Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 186 SEPTEMBER, 1918 No. 3

GROWING MEDICINAL PLANTS IN AMERICA.*

BY

ALLERTON S. CUSHMAN, Ph.D.,

Lieutenant Colonel, Ordnance Department, N. A.
Formerly Director, The Institute of Industrial Research, Washington, D.C.
Member of the Institute

MODERN warfare may be roughly divided into two distinct phases: one is destructive and the other reconstructive. There are no longer crucial battles which decide the issue of war as at Waterloo or Gettysburg, but there is instead one protracted and unceasing effort to destroy the enemy's life and property on the largest scale possible. Nevertheless, the reconstructive work must follow the destructive on an equally gigantic scale. Never before in the history of mankind has such organization existed for the first-aid and subsequent treatment of the sick and wounded, and never before has there been such concentrated human and animal suffering calling for alleviation.

It is a curious dispensation of Providence that man first found, and still to a very large extent depends for his remedial and anæsthetic agencies on, the familiar herbs and weeds which grow wild about his woods, fields and hedgerows. The term "drug" includes all substances used as medicines, as well as those substances which may be misused as intoxicants or anæsthetics. Drugs may be mineral, such as the bromides, iodides, and chlorates of potassium, the mercurial, arsenical, and silver compounds and many others. In addition to these, modern medicine depends largely on the coal-tar derivatives, among which may be mentioned some of the more familiar, as, for instance, acetanilid,

* Presented at the stated meeting of the Institute held Wednesday, April 17, 1918.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

COPYRIGHT, 1918, by THE FRANKLIN INSTITUTE.

phenacetin, and the various salicylates, under such trade names as aspirin and salol, owned and exploited before the war exclusively by the Germans. The present paper, however, concerns itself particularly with the raw materials from which such medicinal agents as the alkaloids and glucosides are extracted. These are represented by morphine, cocaine, strychnine, atropine, quinine, digitalin, strophanthin aloin, etc., which are extracted from crude drugs imported into this country from overseas.

FIG. 1.

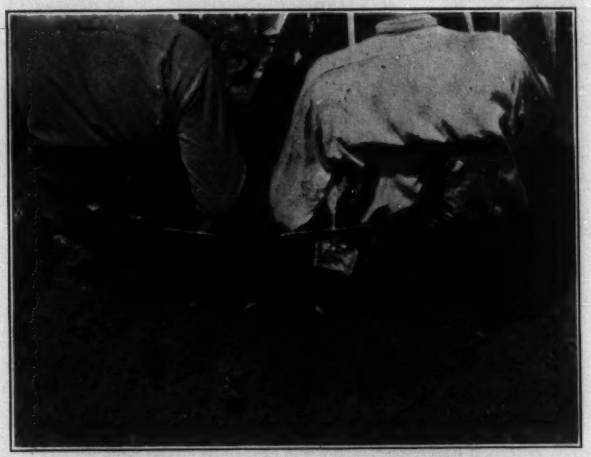
Planting belladonna seedlings at the rate of sixty to the minute.

It is, however, more particularly the botanical drugs which can be grown under proper scientific control in the United States which we shall consider. Among these we find the following important medicinal plants: Aconite, belladonna, and stramonium, the principal source of atropine, digitalis (foxglove), cannabis indica or Indian hemp, the active principal of which is known in India as hashish, the properties of which the elder Dumas so beautifully misdescribes in "The Count of Monte Cristo."

Among our native medicinal plants we also use in fairly

large quantity henbane, rhubarb, senna, gentian, golden seal (hydrastis), senega, mandrake, bloodroot, arnica; ajowan seeds, and monada punctata, used in the manufacture of thymol, a specific in the treatment of the hookworm disease, and many others too numerous to mention. If a layman, unaccustomed to the study of such subjects, were to pick up one of the great New York commercial daily newspapers which quote prices in the drug markets and were to glance over the items quoted he would probably be

FIG. 2.



A close up view of the two-man planter by means of which belladonna seedlings are set out.

very much astonished at the familiar herbs, roots, and flowers which are made a matter of almost daily barter and sale, the manifold uses of which constitute some of the mysteries of our enormous patent medicine industry. There are warehouses in the heart of New York City filled with great bales of things familiar to our childhood days: cornsilk, daisy tops, red clover tops, laurel leaves, skunk cabbage, flagroot, burdock, dandelion, gentian, lily-of-the-valley, wintergreen, and many another of our old friends of the fields and woods. The inquirer might also be surprised to

phenacetin, and the various salicylates, under such trade names as aspirin and salol, owned and exploited before the war exclusively by the Germans. The present paper, however, concerns itself particularly with the raw materials from which such medicinal agents as the alkaloids and glucosides are extracted. These are represented by morphine, cocaine, strychnine, atropine, quinine, digitalin, strophanthin aloin, etc., which are extracted from crude drugs imported into this country from overseas.

FIG. 1.

Planting belladonna seedlings at the rate of sixty to the minute.

It is, however, more particularly the botanical drugs which can be grown under proper scientific control in the United States which we shall consider. Among these we find the following important medicinal plants: Aconite, belladonna, and stramonium, the principal source of atropine, digitalis (foxglove), cannabis indica or Indian hemp, the active principal of which is known in India as hashish, the properties of which the elder Dumas so beautifully misdescribes in "The Count of Monte Cristo."

Among our native medicinal plants we also use in fairly

large quantity henbane, rhubarb, senna, gentian, golden seal (hydrastis), senega, mandrake, bloodroot, arnica; ajowan seeds, and monada punctata, used in the manufacture of thymol, a specific in the treatment of the hookworm disease, and many others too numerous to mention. If a layman, unaccustomed to the study of such subjects, were to pick up one of the great New York commercial daily newspapers which quote prices in the drug markets and were to glance over the items quoted he would probably be

FIG. 2.

A close up view of the two-man planter by means of which belladonna seedlings are set out.

very much astonished at the familiar herbs, roots, and flowers which are made a matter of almost daily barter and sale, the manifold uses of which constitute some of the mysteries of our enormous patent medicine industry. There are warehouses in the heart of New York City filled with great bales of things familiar to our childhood days: cornsilk, daisy tops, red clover tops, laurel leaves, skunk cabbage, flagroot, burdock, dandelion, gentian, lily-of-the-valley, wintergreen, and many another of our old friends of the fields and woods. The inquirer might also be surprised to

learn that these familiar things command a price varying from cents to dollars per pound and he might even solemnly determine to turn his newly acquired knowledge to profitable purposes and forthwith embark in the combination of business and pleasure of producing and purveying herbs and simples. Unfortunately, however, for this laudable ambition, it would soon become apparent that the labor involved, for instance, in gathering two bales of

FIG. 3.

A seven acre field of belladonna ready for the first harvest.

green corn silk or something else which shrinks to one bale on drying is quite inadequately paid for by the prices offered by the stony-hearted buyers in the New York market. In fact, it would probably be learned that, although America produces more corn silk or something else than all of the rest of the world together, from time out of mind the baled corn silk or something else has been imported from overseas where child-labor laws are unknown and where people's wives, mothers, and grandmothers are more interested in acquiring a few extra pennies a day by working in the fields than they are in acquiring a vote.

Seriously speaking, the production of medicinal herbs in America depends very largely on the labor cost, and can be made a profitable enterprise only when it is conducted on a scientific basis and on a sufficiently large scale to absorb the high cost of the labor involved in the tilling, planting, cultivating, harvesting, curing, and packing operations. At the same time, the drug grower faces a most uncertain and precarious market for his wares, for, although his drug plants are needed, the need is strictly limited, and the slightest overproduction is either entirely unsalable or salable at a price less than the cost of production.

A well-known authority on drug growing, Mr. H. C. Fuller, has recently said in effect: "The cultivation and marketing of drugs must be done under an entirely different set of conditions than those obtaining in the growing and selling of vegetables. Much that has been published on the subject is misleading, and the idea that the ordinary farmer can successfully grow drug plants and produce a marketable article is ridiculous. It can be confidently asserted that if the ordinary farmer should undertake the growing of drug plants it would result in failure to him as well as discredit to the efforts of those who are specializing in the subject."

Dr. W. W. Stockberger, the Expert of the United States Department of Agriculture, in charge of drug and poisonous plant investigations, expresses the same fact in the following words:[1]

"If medicinal plant cultivation is to succeed in this country it must be placed on a sound commercial basis, and there are good reasons for believing that this end will not be attained by encouraging a large number of persons to engage in drug growing on a small scale." . . . "If the drug manufacturer is to become permanently interested in medicinal plants produced in this country he must be assured of a fairly large and dependable source of supply. For this reliance must be placed upon well-equipped growers who have sufficient capital to carry on the enterprise effectively."

Still another writer on this subject has recently published the following comments:[2] "In the strictly pharmaceutical field the shortage of crude drugs has been felt more or less keenly since

[1] *The Druggists' Circular*, January 18, p. 5; *ibid.*, March 18, p. 106.
[2] JOURNAL FRANKLIN INSTITUTE, vol. 185, No. 3, p. 435.

1914, and much misinformation and little information of value have been circulated on the subject. Stocks of many crude drugs have been exhausted, and the cultivation of medicinal plants has not as yet assumed any great proportions in the United States. Those drugs which were obtained from Europe were not cultivated, but grew wild there. It was therefore a simple matter to have them gathered and prepared for market at comparatively small cost. The cultivation of medicinal plants in the United

FIG. 4.

Women harvesting belladonna leaves.

States requires expert labor, the production of artificial conditions of soil and moisture in order to provide as nearly as possible the conditions under which the plants grow in their native habitat, and considerable investment of money. Drug plants have been raised on an experimental scale by the Government and in the drug gardens of various colleges, but it is a very different undertaking to raise them on a commercial scale. American growers of crude drugs were confronted with the necessity of increasing the value of the plants in order to overcome the high cost of cultiva-

tion. It was soon found that cross-pollination would not produce plants containing more active constituents than they do normally, but by careful selection of seed it has been possible to increase the amount of active constituents in such plants as belladonna, digitalis, etc., to three or four times what the Pharmacopœia requires. Furthermore, advanced methods of harvesting these plants have made it possible to secure three or four harvestings in one season, whereas in former years one or two was the limit."

FIG. 5.

Harvesting digitalis leaves.

The experience gained by the author in the production of certain drug plants extending over the past three years confirms the statements of the experts quoted above. The fact is very clearly brought out that the so-called "backyard" movement, however much it may stimulate vegetable gardening and poultry raising, is not applicable to the growing of medicinal plants. The U. S. P. requirement for dry belladonna herb or leaf calls for an assay showing a content of not less than 0.3 per cent. atropine alkaloid.

Any substantial quantity of active constituent in excess of this prescribed minimum should, if the producer is aware of it, be credited in the price paid by the consumer. The small producer can have no knowledge of the assay value of his product unless he employs the services of a chemical laboratory. Such chemical assays require special highly paid experts in order to obtain accurate results, and the cost of such service is naturally high. In the opinion of the writer, unless a producer is able to hold

FIG. 6.

A field of cannabis.

his belladonna to an assay value at least twice as strong as the U. S. P. requirement it would not be worth producing at all under American conditions. Such high-potency crude drugs can be obtained only by the application to the problem of trained scientific knowledge. Plant breeding through seed selection and a knowledge of just the day to harvest when the alkaloidal content is at the maximum, together with proper control of the drying operations, constitute a large part of the secret of success. All this necessarily hangs upon the results of laboratory investigation, which

must go on hand in hand with the agricultural operations. The author and his associates have produced belladonna in bulk running almost one per cent. alkaloid-atropin.

Other important medicinal crops, such as digitalis and cannabis, present a special problem, inasmuch as the active constituents are not determinable by chemical assay, but depend upon certain specific physiological tests which require the services of another group of trained specialists.

FIG. 7.

The Institute of Industrial Research, Washington, D.C., where the drug plants are analyzed and tested.

In marketing crude drugs the pharmacopœial requirements must be met, no matter how irrational these may be. The requirement on cannabis calls for the dried flowering tops of unfertilized pistillate or female plants only. This specification requires that before the male plants pollinate experts must go over the entire crop, plant by plant, and distinguish and destroy every male individual. Immediately the visible crop shrinks approximately fifty per cent., and also adds to its cost of production the cost of this wholesale weeding operation. This requirement

also necessitates the seed gardens being remote enough from the main crop to prevent wind-blown pollen from reaching the female survivors. In order to test the necessity for this requirement, the author, in coöperation with Mr. H. C. Fuller, gathered from the seed gardens flowering male tops, which were dried, powdered, and bottled. This sample, together with a pharmacopœial sample bearing distinguishing numbers but no other information, was sent to the physiological laboratory of the Harvard Medical School.

FIG. 8.

Preparing to fill the dryer where the herbs and roots are cured.

The report showed the male sample was the more physiologically active of the two. Although the pharmacopœial requirement is probably a survival of some superstition originating in India, the drug-plant grower is held rigidly to it, and it is extremely unlikely that any buyer would purchase the crude drug in the powdered form, as the dried flowers must be present so that inspection will detect the presence of male plants. If such specifications are annoying to the commercial drug grower, they would be found intolerable by an ordinary farmer who might otherwise feel inclined to undertake the production of this special crop.

All medicinal plants are intensely poisonous to animals, but, curiously enough, most of them are very attractive to predatory insects. Possibly insects share with man a weakness for certain things that would better be let alone. However this may be, the author has determined by actual experiment that the flea beetle consumes about five per cent. of every crop of belladonna grown, in spite of the most liberal use of insecticides and agricultural spraying machinery.

Henbane, the crude drug from which hyoscyamine is made, sells at about four dollars a pound on the dry basis, and is worth it, owing to the eagerness with which insects appear to lie in wait for every green shoot as it appears. In the course of the author's experience potatoes were grown in the neighborhood of henbane, in the hope that it would act the part of a decoy crop. Unfortunately, however, the potato beetles preferred the henbane, and—if we may be permitted to drop into the vernacular—returned to their own homes only after all the other places were shut up.

Among the medicinal plants which the author and his associates have attempted to grow commercially in Virginia and Maryland, many of them successfully, are belladonna, digitalis, cannabis, sage, hydrastis, ginseng, stramonium, monada punctata, pinkroot, valerian, senega, colchicum, etc. Of these, the first two have to be propagated in a greenhouse during the winter in order that the plants, when set out in the field, will be large and vigorous enough to cope with the ravages of insects and crowding out by weeds. The greenhouse soil has to be especially sterilized to prevent the spread of a special fungoid root-rot disease to which belladonna is especially susceptible and which follows the seedlings from the greenhouse to the open fields. During one season the writer lost over fifty per cent. of his belladonna crop, due to root-rot. So suddenly did the disease show itself that on one day the bushy plants, about two feet high, were flourishing in the field and the next day were found wilted down and dying. The roots of belladonna are rich in atropine and are usually dug up and sold after a succession of leaf crops have been gathered, so that the loss from root-rot is most discouraging and baffling.

Ginseng and hydrastis (golden seal) grow in leafy, shady woods and are much appreciated by field mice, which seem to feel that the crops are being grown for their exclusive benefit. Moles,

although they do not appear to eat the roots, are most destructive and prefer to burrow along a line of valuable plants rather than go anywhere else. Ginseng is not used as a drug in any country except China, so, if grown, it is only for export. It is doubtful if, under present conditions, its cultivation can be carried on profitably in this country except by specialists in this crop.

This paper has not attempted to discuss drugs or drug growing in their technical aspects, but merely describes a few of the conditions and difficulties encountered by a group of associates who entered the field with no expectation of making large profits, but with the patriotic purpose of demonstrating, if possible, that American methods were capable of making us independent of central Europe with respect to some very necessary medicinals.

Determining the Freshness of Eggs by Photography. G. A. LEROY. (*Comptes Rendus des Seances de l'Academie des Sciences*, vol. 165, No. 25, p. 1026, December 17, 1917.)—Palming off as fresh, eggs that are several weeks or even months old is quite a common fraud, especially at present, when war-time conditions have caused a scarcity of the product and increased the cost. In the trade, eggs are classified according to freshness by the process known as *candling*, consisting in observing their transparence, which depends mainly upon the dimensions of the air-spaces. With a view to its value in legal expert testimony, the author has developed a more precise method of visualizing the contour of this air-space in such a manner that it constitutes a permanent and comparable legal exhibit. This result has been secured by photographing the eggs by transmitted light upon extremely rapid plates. In this way the contour of the air-space, recorded in true dimension, can be accurately measured. In the course of experiments it was found that radiography yielded distorted images quite inferior to those obtained by visible light.

A large amount of practical information on candling and other features relating to the egg industry will be found in the following publications of the U. S. Department of Agriculture: Professional Paper No. 51, July 20, 1914; No. 224, April 28, 1916. Yearbook Separate 552, 1910; 596, 1912; 647, 1914. Bureau of Chemistry, Circular No. 98, July 31, 1912.

SOME POINTS REGARDING CALORIMETER EFFICIENCY.*

BY

WALTER P. WHITE.

Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C.

THE use of the calorimeter is to-day extending rapidly, especially for fuel testing. At the same time, some new types of calorimeter are being introduced whose value varies greatly according to the work to which they are put. There is thus a double reason for considering the sources of calorimetric error and the advantages of different types of instrument. The present paper attempts this task, and does so with reference rather to the moderately high precision desirable in commercial work than to the higher precision attained in special researches.

Calorimetric experiments are practically always done by passing the heat to be measured into a known mass of water and observing the resulting temperature rise. The heat, ΔQ, is then determined in accordance with the well-known equation: $\Delta Q = C \Delta \theta$, where $\Delta \theta$ is the temperature change and C the capacity for heat of the calorimetric body; that is, of the water together with the containing vessel. This determination would involve nothing but a couple of temperature measurements were it not for the fact that there is no insulator for heat, and that therefore there is practically always some heat flowing to or from the calorimeter. This *thermal leakage* must be determined, usually by a combination of observations and calculations. It causes less actual error than is often supposed, but it dominates the whole subject of calorimetry, and is responsible for nearly all the characteristic features of calorimetric practice. Thus, in order to treat the leakage in a definite way the surrounding temperature must be controlled more or less; then, in order to prevent the leakage from making the calorimeter temperature non-uniform and therefore uncertain, there must be stirring, which is the reason for using a liquid. This, in turn, may bring difficulty from evaporation and irregular stirring, and, finally, some tem-

* Based on a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, November 15, 1917.

perature differences remain uncorrected (especially in the solid parts), constituting "lags," which are, mathematically, the most complicated part of the whole subject, though they can, fortunately, be handled very simply in work of moderate precision.

Aside from blunders and exceptional occurrences, the sources of error in ordinary calorimetry seem completely covered by the following list:

A. The main temperature measurements.
B. The value taken for the heat capacity of the calorimetric body.
C. The associated determination.
D. The thermal leakage or its consequences, including:
  a. Control of the external temperature.
  b. Control of the calorimetric temperature (*i.e.*, efficiency of stirring).
  c. The heat produced by stirring (which may be irregular, owing to irregular speed of stirring).
  d. Evaporation.
  e. Lags, if neglected or varying.

A. The temperature measurement seems to call for little comment, save perhaps to say that from two to four individual observations are needed, so that the final error *may* be two or four times that of a single reading, though the *average* final error will not be so large as that. Thus, a mercury thermometer, if accurate to 0.001°, will, in itself, give a precision of 1 per mille or a little better with a temperature rise of 4°; this is, however, rather high precision for a mercury thermometer. The electric (resistance) thermometer will do better—about ten times as well with the best instruments in competent hands. It, of course, requires a more elaborate installation. Many observers, however, consider the precautions and corrections needed with it less objectionable than those involved with the mercury thermometer, and the extra precision of the electric thermometer is a desirable thing, even in cases where the other may seem good enough. A precision which is just enough and no more for the purpose in hand looks very shrewd and economical, on paper, and may prove not unsatisfactory so long as everything goes well; but if unexpected errors need investigation or checks upon the accuracy are desired, as is pretty certain to happen sooner or later, it is exceedingly comfortable to have even a four- or five-fold excess of

precision, and in as many departments of the work as possible. The *thermo-electric* thermometer is not only capable of higher ultimate precision than the resistance thermometer in measuring small temperature differences, but is, to judge from my own experience, more reliable, and less troublesome in its need for precautions, though in some other evident ways it is less convenient. The methods necessary with it, however, are not so generally understood, and it is not regularly manufactured at present.

B. For determining the heat capacity of the calorimetric body the practice of calibrating by means of a known quantity of heat, obtained either electrically or by means of a standard substance, has so many advantages, and has already become so widely used, that no other seems to deserve consideration. With this method, if uniform conditions are preserved, the error of the calibration becomes little more than the average error of a number of determinations, which can be made as numerous as is desired.

C. The associated determination must be considered for a fairly evident reason. There is no such thing as bottling up a quantity of heat for subsequent measurement; heat cannot even be passed, unchanged, directly from one calorimeter to another. The heat must be produced as measured, and the only way to give the measurement significance is to express it as a ratio between the quantity of heat and the quantity of the thing (reacting chemical, electric energy, etc.) yielding the heat. An error in one of the terms of this ratio has the same final effect as a corresponding error in the other. This is merely a formulation of what is pretty generally understood in individual cases. In commercial coal testing, for instance, it is generally recognized that the sampling of the coal is often the greatest source of uncertainty, and it is futile to strive for a calorimetric precision very far ahead of the uniformity which it seems worth while to seek in the sampling.

D. The *thermal leakage* and its calculation are responsible, as has been said, for most of the problems and complications in calorimetry. In calculating, the leakage is taken as the product of the *leakage modulus*, or rate of leakage per degree of *thermal head* (thermal head: difference of temperature between calorimeter and environment), multiplied by the integrated value of the thermal head for the experimental period. The standard method is to determine the leakage modulus by *rating period* ob-

servations on the rate of cooling of the undisturbed calorimeter; if two such rating periods are used it is possible to determine the thermal head without measuring the environing temperature, provided this temperature does not change appreciably during the experiment. This procedure also eliminates the effect of the heat produced by the stirring, which would otherwise need especial attention. The method is familiar, and does not need detailed consideration here. This method is almost necessary if the environment consists of several indefinite bodies at different temperatures, but it involves having three observation periods. If, however, the leakage modulus is the same from day to day, and if the environing temperature is measured, or is kept at a known value by a thermostat, the leakage can, after suitable preliminary work, be determined merely from observations on the calorimetric temperature during the experimental period, and no other period is needed, unless occasionally as a check. Of course, this demands (1) that the environment be all at a single definite temperature—that is, practically, that it be a stirred body of water more or less completely enclosing the calorimeter (though with an air space between, of course), and (2) that the calorimeter always contain the same amount of water and be located, to a fraction of a millimetre, perhaps, always in the same position within the jacket.

To determine the leakage in this way not only saves time and labor, but even promotes accuracy by eliminating the errors of the temperature measurements needed in observing the leakage rates. That is to say, instead of a rate determined separately, with some error, for each experiment, the observer uses a rate determined once for all with more accuracy by numerous experiments. Using this method, the Bureau of Mines observers have, as they state, usually attained in their regular routine procedure, an agreement of 1/7000, which closely approaches the best yet reported for the most elaborate special researches. Of course, this precision was realized only where the sampling error was eliminated, and it is more than is needed in regular work, even for the Bureau of Mines. This method, it may be added, should not be relied upon in any particular installation until it has been shown that the leakage modulus is in fact as constant as it needs to be. Other things than the position of the calorimeter may be of importance here. For instance, if metallic parts of any kind run from the

calorimeter through the jacket to the air of the room outside it, a change in room temperature is very apt to alter the leakage rate unless proper precautions are taken. Evaporation is prevented in the Bureau of Mines calorimeters.

If the determinations made are nearly the same day after day, the temperature during the experimental period will always rise along almost the same curve, and its integrated value may without error be taken as the same for any given total temperature rise. If, in addition, the jacket temperature and the initial calorimeter temperature are always the same, the integrated thermal head will always bear the same relation to the total temperature, and the amount of thermal leakage will be simply a certain constant (and small) percentage of the total temperature rise. No attention, therefore, need be paid to the thermal leakage in working up the results. This is essentially the Bureau of Mines procedure. This treatment of the thermal head saves only a little labor, not time or error, and hence is much less important than making the jacket a thermostat. It is, however, a fact of some importance that where the determinations made are sufficiently alike a faulty treatment, or even a total neglect, of the thermal leakage will usually produce no great error in a calorimeter *calibrated by the user*, if the jacket is complete and is maintained constant.

D, a. The temperature change from leakage of a well-designed calorimeter of ordinary size will be less than 0.015 of the thermal head in five minutes; hence for five-minute experimental periods the uncertainty of the jacket temperature may be at least thirty times that in the principal readings. Evidently any difficulty there may be as to this temperature will be a matter of control or uniformity, and not of measurement.

D, b and *c.* The matter of stirring seems fairly well covered by the recommendation of the joint committee on coal analysis of the American Society for Testing Materials and of the American Chemical Society,[1] that the stirring be vigorous enough to heat the calorimeter nearly 0.001° per minute, and regular enough so that the variation in heat is negligible. This is certainly sufficient with a reasonably well-designed calorimeter. The heat varies as the cube of the speed of stirring, so that a variation of

[1] *Jour. Ind. and Tech. Chem.*, 9, 106 (1917).

1 per cent. in speed produces a variation of 3 per cent. in heat production.

D, d. No data exist as to the relative probable error from evaporation, but this does not seem likely to be serious in commercial work so long as evaporated water does not condense on the cover and drop back into the calorimeter. The prevention of evaporation is very desirable in work of high precision and is easy enough to be reasonable in nearly all cases, since it can be effected, without the introduction of any other error, by covering the calorimeter with an exceedingly thin metal cover. This cover need not bend down to touch the water, though it may well do so. If it does not, the water should be, to a millimetre, always at the same distance below it—say a centimetre. Covers of wood, rubber, or other poorly conducting material have no other recommendation than possible cheapness. (A proof of this statement will be published later.) It does not necessarily follow that it is desirable to scrap such covers now in use, however.

Further Practical Conclusions.—(1) From the preceding discussion it appears that uniformity of conditions is, in the uniform determinations of commercial work, almost sufficient in itself to secure precision, so far as thermal leakage is concerned, since effects which would otherwise be errors tend to cancel. The joint committee report cited above says that the calorimeter jacket "should" contain water, which is stirred. There are two different reasons for this. The uniform temperature of a stirred jacket is, of course, desirable, but it might not seem necessary, since an unstirred jacket always started at the same temperature relative to room and calorimeter would be likely to give *uniform* results. But to have a jacket full of water which is stirred is the easiest way to provide for getting it at the same relative temperature each time; moreover, the provision of this particular feature is seldom likely to prove expensive.

(2) To convert the stirred jacket into a thermostat is more expensive, since it requires a regulator and also demands if it is to be of real value that the jacket be brought *above* the calorimeter so as to surround it with practical completeness. But the gain in time and labor, as well as in accuracy, from using such an installation is very considerable.

(3) The joint committee report advises having the initial calorimeter temperature so far below that of the jacket that the

final temperature is less than a degree above it, and the total resultant thermal leak is near zero. Two advantages are attributed to this procedure: one, that evaporation is diminished; the other, that the total leak is small. The diminution of evaporation is as likely to increase the error as to decrease it,[2] and the smallness of the total leak is practically of no advantage in the case treated, where two rating periods are supposed to be run, since in that case the total magnitude of the leakage has no effect on the error. (This appears to be a fact not generally known. Proof of it will probably be published later elsewhere.) Little is *lost* by thus reducing the total amount of leakage, but it would be misleading, in considering the adoption of this method rather than some other, such as the Bureau of Mines method, to suppose that it had any real advantage in this particular direction.

(4) A calorimeter has been advertised as "adiabatic" which is characterized mainly by the use of a vacuum jacketed glass vessel instead of the usual metal cup. To call such an arrangement adiabatic is pure humbug; it has a thermal leakage, which may be one-third or may be one-fourth as great as that of an ordinary calorimeter. To claim *some* advantage from the smaller leakage is legitimate; for it may enable an equal degree of precision to be reached with less care as to conditions.

(5) Attempts are making to utilize in commercial work calorimeters which are really adiabatic; that is, in which the jacket temperature can be rapidly changed and controlled so that it can be kept the same as that of the calorimeter during an experiment. Some of the proposed apparatus is admirable in its ingenuity and effectiveness, but there is still reason to doubt if it is worth while. The adiabatic method in calorimetry, like most methods in every subject, differs greatly in value according to the conditions of its use. In aneroid (fluidless) calorimetry and in long-timed determinations it is often absolutely indispensable, but in short experiments its value is much less. If we refer to the sources of error listed in this paper, *A*, *B*, and *C* are scarcely affected one way or the other by the adoption of the adiabatic method; nor are the temperature distribution effects *D*, *b*, *D*, *c*, and *D*, *e*. Evaporation (*D*, *d*) is greatly diminished, but easier

[2] Owing to the fact that the leakage rate differs some 30 per cent., according as evaporation is or is not occurring; that is, suddenly becomes 30 per cent. greater when the calorimeter temperature passes above the jacket temperature.

ways have already been given of securing this result, which is not of first importance, anyway, in commercial work. The control of jacket temperature (D, a) will evidently be more perfect where this temperature is not greatly changed, so that here the adiabatic method is actually worse, though the inferiority is probably not serious. One real advantage of the adiabatic method is in ease, not precision, and consists in the avoidance of the labor of calculating the thermal leakage. But in commercial work this advantage is still more easily obtained through a thermostat, as at the Bureau of Mines. Of course, this method calls for a constant leakage modulus, which the adiabatic does not. But the results show that the chances of error from inconstancy of this modulus are very small. The most serious danger of variation in the modulus, that coming from the influence of room temperature changes, is quite as great with the adiabatic method. In *uniform short-timed* determinations, then, the adiabatic procedure, in return for the expense and manipulation it demands, appears to offer no advantage that cannot be more easily secured in other ways.[3]

(6) If a massive block of metal is used as the calorimetric body, equalization of temperature is less perfect than with a stirred liquid, but the difficulties and annoyances of stirring and evaporation are completely banished. The relatively imperfect equalization is evidently less serious in the uniform determinations of commercial work, so that for such work this kind of calorimeter might prove very desirable. Féry has proposed such an instrument, using the steel bomb alone as the calorimetric body, and measuring temperature thermo-electrically. In striving for simplicity, he has, as it seems to me, attained an altogether unnecessary crudeness in several respects. Apparently, a much more

[3] In some recent work of high precision (*J. Am. Chem. Soc.*, 39, 2110, 1917) the adiabatic method was adopted mainly because a stationary final calorimeter temperature was thought necessary for satisfactory reading of the resistance thermometer. It is safe to say that the necessity, in so far as it existed, may fairly be attributed to some deficiency or peculiarity of the electric installation used, and is not an inevitable disadvantage of that type of thermometer, although the usual installation is not the most convenient that could be used for reading changing temperatures. So far as the precision of commercial work is concerned, there appears to have been no general difficulty in reading changing temperatures, as is indeed shown by the disregard of the possibility of making their reading more convenient.

accurate instrument could be realized which would not be harder to manipulate. The final success of such an instrument—that is, its net superiority to existing calorimeters—cannot be guaranteed in advance of actual experience, but the idea seems promising.

In conclusion it may be said that a calorimetric installation with a stirred, thermostated jacket and an electric thermometer appears thus far to have given the best combination of precision and ease of operation, and that in the main the electric thermometer is responsible for the precision, the thermostat for the ease of operation.

High-strength Steel from Nickel-copper Iron Ore. ANON. (*Engineering News-Record*, vol. 80, No. 17, p. 812, April 25, 1918.) —Large-scale experiments to produce a high-strength steel from Sudbury ores, in which both copper and nickel are combined with the iron, show that a metal giving test results quite equal to those of nickel-steel as used for bridges and for forgings can be produced at low cost. The new product has been named "Nicu" steel and is made by the Nicu Steel Corporation, East Montreal, Canada. Material with an ultimate strength of 70,000 to more than 100,000 pounds per square inch, a yield-point of 50,000 to 80,000 pounds per square inch, and of satisfactory ductility for bridge or ordnance purposes is produced at costs which may be brought down as low as $30 to $35 per ton.

Figures of tests on the material produced in the experimental smelting are given by Lieut.-Col. R. W. Leonard in a paper read before the Canadian Society of Civil Engineers, March 28, 1918. In ten heats run at East Montreal, steel was produced having carbon content from 0.17 to 0.73 per cent., silicon from 0.012 to 0.032 per cent., sulphur always below 0.048 per cent., and phosphorus generally below 0.01 per cent. The sum of nickel and copper ranged from 1¼ to 2½ per cent., copper usually being about one-fifth of the total. A typical strength test, one made by Dr. Alfred Stansfield, of Magill University, Montreal, resulted in a tensile strength of 96,500 pounds per square inch, a yield-point of 52,800, an elongation (in two inches) of 24.3 per cent., a reduction in area of 50.8 per cent., and a 180-degree bend test flat without cracking. This was a specimen of "Nicu" steel in which the combined nickel and copper was 2.26 per cent. For comparison it may be noted that 3¼ per cent. nickel-steel is commonly specified to have an elastic limit not below 50,000 pounds per square inch and ultimate strength of 85,000 to 100,000 pounds per square inch, with an elongation of 16 to 17 per cent. in 8 inches, and a reduction in area greater than 30 per cent. "Nicu" steel, it is stated, has not as yet been manufactured on a commercial scale.

Direct smelting of nickel-bearing iron ores to nickel-iron pig has been done in the past. With the same purpose of producing a copper-free nickel alloy, much study has been given the Lake Superior nickel-copper-iron ores to produce nickel pig and nickel steel with minimum admixture of copper. On the other hand, nickel-copper steel has been made in the United States in several instances by adding monel metal to steel.

Concrete Metal Planing Machines. E. VIALL. (*American Machinist,* vol. 48, No. 15, p. 603, April 11, 1918.)—The urgent demand for speed of construction incident to war-time activity is giving rise to some radical departures from established practice in engineering construction. A notable example is found in the recent rapid development of the relatively old idea of building vessels of reinforced concrete. Ships of several thousand tons built of this material are now under construction. Another remarkable innovation is found in the method of lathe construction employed by Lucien Q. Yeomans, in which the ways are made of cold-rolled shafting held in place in the unfinished bed-casting by the use of Babbitt metal. The latest remarkable departure by the same builder is in the application of reinforced concrete to replace cast-iron in the structure of large metal-planing machines.

These machines were built by the Amalgamated Machinery Corporation, Chicago, Ills. They comprise a battery of four machines, each with a bed 184 feet long, 17 feet across at its widest place, and 18 feet in height, measured from the bottom of the bed to the top of the housing. Approximately 212,000 pounds of iron and steel castings were used in each machine, and about 13,500 cubic feet of concrete reinforced, with 34,000 pounds of steel bars. The bed consists of a concrete girder with a high percentage of steel reinforcement surmounted by relatively shallow cast-iron ways. The depth of the girder over the ways is 8 feet 6 inches. The ways are made in sections 12 feet long, 4 feet 10 inches wide, and 13 inches through at the deepest point, and have one flat and one V-guide 10 inches wide. The table is also made in sections about 12 feet in length. After the sections have been fastened together concrete is poured into box-like sections, making one long, solid monolith of concrete and iron.

No automatic means of feeding is supplied; each cutter head is controlled independently by hand from a platform at the top of the housings. The power required is furnished by two 40-horsepower, three-phase, sixty-cycle motors, making 1800 revolutions per minute. The machines were built primarily for the purpose of planing the beds of large gun-boring machines for the government. While built alike for a special purpose, they may be made in various sizes if necessary, and the short time needed to complete them should make the system of construction employed a valuable innovation where the greatest economy of time is imperative.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.

BY

JOSHUA J. SKINNER, Ph.D.

1. *In Soils from Widely Different Sections.*—The soils examined were from various parts of the United States; soils from twenty states make up the list. They vary from very unproductive to extremely fertile soils. Aldehydes were found in soils from nine states as widely separated as New York and Mississippi or Oklahoma. Its presence is therefore not confined to any locality.

2. *In Soils of Different Texture.*—The soils in which aldehyde occurred are not soils of any specific type or texture. The above list of soils containing aldehyde comprises clays, clay loams, silt loams, silty clay loams, loams, stony loams, fine sandy loams, and very fine sandy loams. There is therefore no apparent relation with soil type or texture.

3. *In Unproductive Soils.*—The unproductive soils examined can be divided into two classes: (1) Garden soils, comprising soils which have been highly fertilized and manured, heavily cropped and intensively cultivated, and later failed to produce good crops. This class includes several greenhouse soils. (2) Field soils, growing general farm crops with ordinary farm methods of cultivation.

Fourteen poor garden soils were examined, five of which contained aldehydes. All of these soils were very unproductive and failed entirely or grew very poor garden crops. Nine of the thirty unproductive field soils examined contained aldehydes.

4. *In Productive Soils.*—Of the thirty productive soils examined, three contained aldehydes. These were the Aurora silt loam, from Miller County, Missouri; Norfolk very fine sandy loam, from Pender County, North Carolina and Dekalb silt loam, from Preston County, West Virginia.

---

* Continued from page 186, vol. 186, August, 1918.

5. *In Acid, Alkaline, and Neutral Soils.*—It is interesting to note that some of the soils which contained aldehydes were acid, some neutral, and others alkaline. Three of the garden soils were acid, one was alkaline, and one was neutral. Of the field soils which contained the aldehyde, ten were acid, one alkaline, and one neutral.

6. *In Soils Growing Different Crops.*—Four of the soils which were found to contain aldehydes were garden soils and had been used for growing garden crops continuously for several years. One was a greenhouse soil and had grown carnations and roses. Twelve of the soils in which aldehyde was found were used for the growth of general field crops. A rotation of several crops was practised on most of these soils. At the time the samples were collected three were in grass, four were growing corn, three were growing cotton, one was in wheat, and one was fallow. These observations, together with the fact that no aldehydes were found on other soils growing the same crop, would seem to indicate that no close relation exists between the crop being grown and the presence of aldehyde.

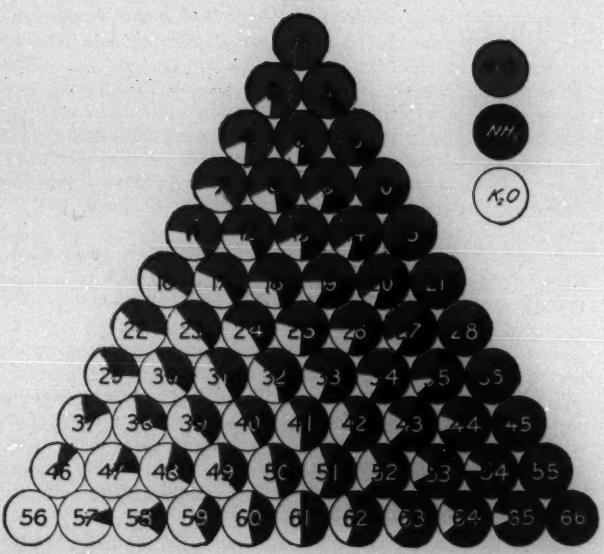
EFFECT OF ALDEHYDES ON PLANTS IN SOLUTION CULTURES.

A thorough study of the action on plants of six aldehydes was made and reported in the following pages. The investigation concerned itself with the action of salicylic aldehyde, vanillin, heliotropine, benzaldehyde, formaldehyde, and paraformaldehyde on plants, first in distilled water and then in nutrient-culture solutions. The two compounds, salicylic aldehyde and vanillin, which have been definitely identified in soils, were further studied in soils in pots and in the field, the results of which are given in a later section. It has not been possible thus far, nor has it seemed wise, to study all of these aldehyde compounds in field experiments. These two were selected for this more extended study which were definitely known to occur in soils. In this section are given the experiments with each compound in water- and nutrient-culture solutions.

CULTURE SOLUTIONS.

In studying the effect of these aldehydes on growth, wheat seedlings were grown in aqueous solutions containing the ordinary fertilizer salts, calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained calcium acid phos-

FIG. V.



Triangular diagram, with the circles representing the 66 culture solutions numbered.

phate only, some sodium nitrate only, and some potassium sulphate only. Other solutions were composed of mixtures of two salts—sodium nitrate and calcium acid phosphate, sodium nitrate and potassium sulphate, and calcium acid phosphate and potassium sulphate. Still other solutions had all three constituents in various proportions. The concentration of all the solutions was 80 parts per million of the fertilizer ingredients, P_2O_5, NH_3, and K_2O. In cultures containing only one fertilizer salt—for instance, calcium acid phosphate—the concentration was 80 parts per million of P_2O_5. If two salts were present—for instance, calcium acid phosphate and sodium nitrate—the concentration was 80 parts per million of $P_2O_5 + NH_3$. If all three salts were present, the concentration was 80 parts per million of $P_2O_5 + NH_3 + K_2O$. The ratios of these constituents varied in 10 per cent. stages. In all there were 66 different cultures of nutrient solutions.

The triangular diagram, as suggested by Schreinemachers (40) and later by Bancroft (4), which had been of great service in physical chemistry where consideration of percentage composition of three component parts is concerned, is used as a guide. This system has been extensively used by Schreiner and Skinner (50, 51, 54, 56) in nutrient-solution studies. The diagram is shown in Fig. 5: it is an equilateral triangle in which the extreme circles at the angles represent 100 per cent. respectively of the ingredients, P_2O_5, NH_3, and K_2O, as shown in the diagram. The P_2O_5 is represented in red, the NH_3 in blue and the K_2O in white. Each side of the diagram is divided into 10 equal parts, represented by circles. If we consider the line representing the base of the triangle, it is obvious that the circle which represents 100 per cent. K_2O (56 in the diagram) represents at the same time 0 per cent. NH_3, and the circle 100 per cent. NH_3 (66) likewise represents 0 per cent. K_2O. If we take a point half-way between these two points—for instance, circle 61—we have a mixture of the two salts in equal proportions; *i.e.*, a mixture of the salts represented by that point will be 50 per cent. K_2O and 50 per cent. NH_3. Similarly, circle 16 represents 50 per cent. K_2O and 50 per cent. P_2O_5, and circle 21 represents 50 per cent. NH_3 and 50 per cent. P_2O_5. If we take a circle nearer to either of the corners, we will have a higher percentage of that ingredient and a correspondingly lower percentage of the other. For instance, at circle 59 the composition is 70 per cent. K_2O and 30

per cent. NH_3; at 29 it is likewise 70 per cent. K_2O, but 30 per cent. P_2O_5; at 64 it is 20 per cent. K_2O and 80 per cent. NH_3; at 45 it is likewise 80 per cent. NH_3, but 20 per cent. P_2O_5.

As stated above, circles on the base line 56 to 66 represent mixtures containing no P_2O_5. The next line above this, namely, 46 to 55, represents mixtures containing throughout 10 per cent. P_2O_5, but varying amounts of the other two constituents. Similarly, the line 37 to 45 represents throughout 20 per cent. mixtures of P_2O_5; line 29 to 36, 30 per cent. mixtures of P_2O_5, and so on upward until circle 1, the apex of the triangle, is reached, where the composition is 100 per cent. P_2O_5, as already explained. Similarly, points on the line 1 to 66 represent 0 per cent. K_2O; line 2 to 65 represents 10 per cent. K_2O, but varying amounts of P_2O_5 and NH_3, and so on until at circle 56 the composition is 100 per cent. K_2O. Likewise points on the line 1 to 56 represent 0 per cent. NH_3; line 3 to 57 represents 10 per cent. NH_3, but varying amounts of P_2O_5 and K_2O, and so on until at circle 66 the composition is 100 per cent. NH_3. It is therefore obvious that any circle within the triangle represents a mixture composed of the three constituents, its position in the triangle being determined by the composition; namely, the percentage of the three component parts, P_2O_5, NH_3, and K_2O. For instance, circle 12, being on the 60 per cent. phosphate line, represents this composition of P_2O_5—namely, 60 per cent.—and being at the same time on the 10 per cent. NH_3 line and the 30 per cent. K_2O line it represents 10 and 30 per cent. of these constituents, respectively. The composition of the mixture represented by this circle is therefore P_2O_5 60 per cent., NH_3 10 per cent., K_2O 30 per cent.; *i.e.*, the ratio of these constituents in the fertilizer mixture is 60–10–30, or 6–1–3. Similarly, the point 34 represents a mixture of the composition P_2O_5 30 per cent., NH_3 50 per cent., K_2O 20 per cent., or a fertilizer ratio of 3–5–2.

The triangle therefore represents single fertilizer constituents at the apices or vertices, mixtures of any two constituents along the boundary lines of the triangle, and mixtures of all three constituents within the triangle.

In the following table is given the composition represented by each of the 66 circles in the diagram:

Two sets of cultures were prepared: to one set were added merely the nutrient salts; to a similar set the aldehyde compound

to be tested was added to each culture, in addition to the nutrient salts. The culture solutions were contained in wide-mouth bottles, holding 250 c.c. and 10 wheat seedlings were grown in each culture in a manner similar to that described in Bureau of Soils Bulletin No. 70. The culture solutions were changed every three days, four changes being made in the course of the experiment. The solutions were analyzed for nitrates immediately after each change. The phosphate and potassium were determined on a composite solution of the four changes. Observations on the general development of the plants and the effect on root growth and appearance were made during the experiment and photographs were taken. At the termination of the experiment the green weight was taken and recorded.

For the purpose of preparing the 66 culture solutions needed in this investigation, stock solutions of the three salts—calcium acid phosphate, sodium nitrate, and potassium sulphate—were prepared separately. The salts used were chemically pure salts, and were dissolved in each case in physiologically pure water.

TABLE III.

Sixty-six Possible Ratios of the Three Fertilizer Constituents P_2O_5, NH_3, and K_2O in 10 per cent. stages.

Circle No.	Ratio or percentage composition			Circle No.	Ratio or percentage composition			Circle No.	Ratio or percentage composition		
	P_2O_5	NH_3	K_2O		P_2O_5	NH_3	K_2O		P_2O_5	NH_3	K_2O
1	100	0	0	23	40	10	50	45	20	80	0
2	90	0	10	24	40	20	40	46	10	0	90
3	90	10	0	25	40	30	30	47	10	10	80
4	80	0	20	26	40	40	20	48	10	20	70
5	80	10	10	27	40	50	10	49	10	30	60
6	80	20	0	28	40	60	0	50	10	40	50
7	70	0	30	29	30	0	70	51	10	50	40
8	70	10	20	30	30	10	60	52	10	60	30
9	70	20	10	31	30	20	50	53	10	70	20
10	70	30	0	32	30	30	40	54	10	80	10
11	60	0	40	33	30	40	30	55	10	90	0
12	60	10	30	34	30	50	20	56	0	0	100
13	60	20	20	35	30	60	10	57	0	10	90
14	60	30	10	36	30	70	0	58	0	20	80
15	60	40	0	37	20	0	80	59	0	30	70
16	50	0	50	38	20	10	70	60	0	40	60
17	50	10	40	39	20	20	60	61	0	50	50
18	50	20	30	40	20	30	50	62	0	60	40
19	50	30	20	41	20	40	40	63	0	70	30
20	50	40	10	42	20	50	30	64	0	80	20
21	50	50	0	43	20	60	20	65	0	90	10
22	40	0	60	44	20	70	10	66	0	100	0

For the calcium acid phosphate solution 1.776 grammes of $CaH_4(PO_4)_2.H_2O$ per litre was used. This solution has a concentration of 1000 parts per million of P_2O_5. The sodium nitrate solution was prepared by using 5000 grammes of $NaNO_3$ per litre. This solution is equivalent to a concentration of 1000 parts per million of NH_3. The potassium sulphate solution was prepared by dissolving 1.852 grammes of K_2SO_4 per litre. This solution has a concentration of 1000 parts per million of K_2O.

The amount of culture solution used in each culture bottle being 250 c.c., it follows that every 2 c.c. of these 1000 parts per million stock solutions will represent 8 parts per million in the culture solution when this is diluted to the capacity of the bottle; *i.e.*, the successive addition of 2 c.c. of the stock solution gives the 10 per cent. differences desired in putting up the 66 solutions. In putting up the 66 cultures it was found desirable to calibrate each bottle for 250 c.c. capacity and to number them consecutively from 1 to 66. Bottles in which the 250 c.c. mark was either high or low, especially those which would submerge the seeds when filled, were discarded, only those being used which brought the surface of the liquid from one-half to one-fourth of an inch from the top.

These 66 bottles were then arranged in triangular form, as illustrated diagrammatically by Fig. 5.

The necessary amount of the 1000 parts per million stock solution above described was measured from a burette. For instance, in adding the requisite amount of nitrate to the set of culture bottles, the line of bottles 1 to 56 received no nitrate solution, the line of bottles 3 to 57 received 2 c.c. each; the line 6 to 58, 4 c.c. each, and so on, increasing 2 c.c. with each successive line, the culture No. 66 finally receiving 20 c.c. of the nitrate solution. Likewise, in adding the requisite amount of potash, the cultures in line 1 to 66 received none, the cultures in line 2 to 65 received 2 c.c. each; in line 4 to 64, 4 c.c. each, and so on up to culture 56, which received 20 c.c. of the potash solution. The phosphate solution is added in the same manner, none to cultures in line 56 to 66, 2 c.c. to cultures in line 46 to 55, and so on up to culture 1, which received 20 c.c.

Each bottle received, therefore, a total of 20 c.c. of one, two, or three of the stock solutions, depending upon whether it was at the apex, along the sides, or in the interior of the triangle.

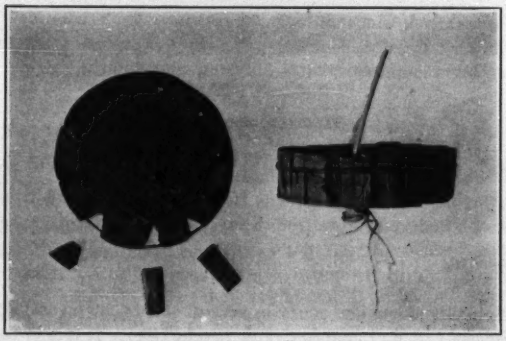
All of the cultures were then diluted up to the 250 c.c. mark.

In this investigation, as already mentioned, the culture solution usually contained 25 parts per million of the aldehyde to be tested. The amount of this compound to be added to each culture

FIG. 6.

Method of germinating many thousand seedlings on perforated aluminum plates floated on the surface of water by means of a sealed glass tube raft in a porcelain-lined tank.

FIG. 7.



Method of mounting the seedlings in the notched corks.

bottle of 250 c.c. was therefore 6.25 milligrammes. Of the 250 c.c., 20 c.c. was already contained in the bottles in the form of the fertilizer salt solution. Therefore the solution with which

the fertilizer salt solution in the bottles was to be diluted consisted of 6.25 milligrammes of the compound dissolved in 230 c.c. of pure water. A sufficient quantity of this strength of solution was prepared to fill the 66 bottles.

As a means of comparing the cultures grown in these solutions containing the aldehyde compound, it was necessary to put up cultures prepared in exactly the same way, except that pure water was used for dilution, as above mentioned.

In all of this work physiologically pure water was used. This was prepared by shaking ordinary distilled water with a highly absorptive carbon black, as described, which removes from the water any injurious property it may possess.

The culture solutions are now ready to receive the plants, which were thereafter grown in a greenhouse under suitable conditions.

In this work it was necessary to have a large number of seedlings of a uniform size. These were germinated on a perforated aluminum disc floated on the surface of a tank of water, as shown in Fig. 6. The seedlings were put in the culture bottles when about one inch high. The method of supporting them in the bottles by means of notched corks is shown in Fig. 7.

In analyzing the solutions the colorimetric methods described in Bulletin 31 of the Bureau of Soils (41) were used for the determination of phosphates, nitrates, and potash.

SALICYLIC ALDEHYDE.

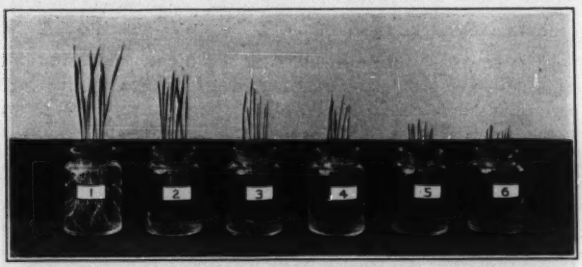
Salicylic aldehyde, $C_6H_4 <^{COH}_{OH}$, the first compound studied is orthohydroxybenzaldehyde. It is an aromatic aldehyde and is easily reduced from the corresponding alcohol, saligenin, $C_6H_4 <^{CH_2OH}_{OH}$, or oxidized to the corresponding acid, salicylic acid, $C_6H_4 <^{COOH}_{OH}$

Salicylic aldehyde occurs in several plants, in several species of Spiræa (18, 84), and in *Crepis fœtida* (83). It is also formed by the oxidation of salicin, a glucoside that occurs in many species of Salix and Spiræa. As pointed out in the previous section of this paper, it occurs in a number of soils, especially soils of low productivity. Its harmfulness to plants was reported in 1914(58).

Effect on Growth.

The effect of salicylic aldehyde was first studied by growing wheat in distilled water containing varying concentrations of the organic compound. Solutions were made containing 10, 25, 50, 100, and 200 parts per million of the aldehyde, and 10 wheat plants were grown in each culture for 10 days. The plants were killed in the three highest concentrations, while 25 parts per million reduced growth material, and even 10 parts per million reduced growth 31 per cent. The appearance of this series of plants on the sixth day is shown in Fig. 8.

FIG. 8.



Effect of salicylic aldehyde on wheat: No. 1, distilled water; No. 2, salicylic aldehyde, 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5, 100 ppm.; No. 6, 200 ppm.

Other plants to which this aldehyde proved harmful in aqueous solutions are corn, cowpeas, and cabbage. This experiment was made in a nutrient solution of calcium acid phosphate, sodium nitrate, and potassium sulphate, with and without aldehyde in varying concentrations. The plants grew in the solutions from May 20 to June 20, 1912; one plant was grown in each culture. Photographs of the cowpeas and corn are shown in Figs. 9 and 10. The green weight results taken at the end of the experiment are given in Table IV.

As seen by the figures in the table, the green weight was materially reduced by the aldehydes. Ten parts per million reduced the growth of the corn from 100 to 60, and in 200 parts per million, the highest concentration used, the corn made practically no growth.

TABLE IV.

Effect of Salicylic Aldehyde on Corn and Cowpeas in a Nutrient Solution. Green Weight of Plants in Grammes.

Treatment	Corn		Cowpeas	
	Green weight	Relative growth	Green weight	Relative growth
Nutrient solution	1.00	100	1.35	100
Nutrient solution + 10 parts per million salicylic aldehyde	.60	60	1.35	100
Nutrient solution + 25 parts per million salicylic aldehyde	.60	60	0.70	51
Nutrient solution + 50 parts per million salicylic aldehyde	.21	21	.35	26
Nutrient solution + 100 parts per million salicylic aldehyde	.21	21	.20	15
Nutrient solution + 200 parts per million salicylic aldehyde	.10	10	.15	11

The cowpeas were also killed in the higher concentrations, while 10 parts per million was not harmful. Twenty-five parts per million, however, reduced growth from 100 to 51, as shown in the last column of the table.

FIG. 9.

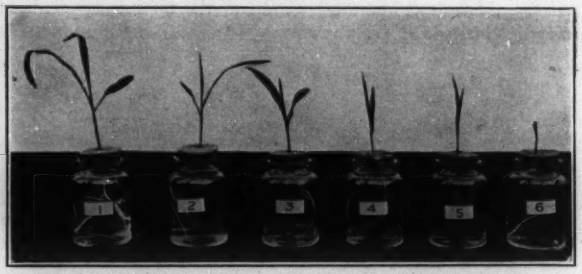
Effect of salicylic aldehyde on cowpeas: No. 1, nutrient solution; No. 2, salicylic aldehyde 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5, 100 ppm.; No. 6, 200 ppm.

In the experiment with young cabbage seedlings the green weights were not taken. Concentrations as high as 50 parts per million killed the young plants, and growth was materially reduced in 10 and 25 parts per million. It was evident that small

amounts of salicylic aldehyde were quite harmful to the young cabbage plants.

These preliminary experiments with wheat corn, cowpeas, and cabbage seedlings show that salicylic aldehyde is very harmful to plants, in very small amounts in aqueous solutions, and that it is severely injurious and kills in amounts higher than 50 parts per million. The roots of all the plants, as well as the tops, were affected.

FIG. 10.



Effect of salicylic aldehyde on corn: No. 1, nutrient solution; No. 2, salicylic aldehyde 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5, 100 ppm.; No. 6, 200 ppm.

Effect in Solutions with Various Fertilizer Ingredients.

The effect of salicylic aldehyde on wheat plants was further studied by growing the seedlings in nutrient-culture solutions containing the ordinary fertilizer salts—calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained the salts singly and some in combinations of two and three, the ratio varying in 10 per cent. stages, as already explained. The solutions were made 66 in number, according to the triangular diagram system. The salicylic aldehyde was used in concentrations of 10 parts per million. The experiment is especially interesting in that it shows the effect of certain of the fertilizer salts in changing the physiological effect of the aldehyde. The effect of the aldehyde on the metabolism of the plant was also studied by analyzing the culture solutions.

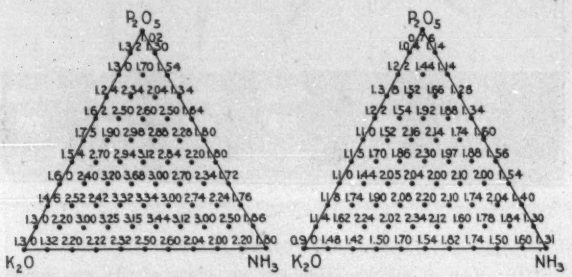
The plants grew in the solutions from May 15 to May 27, four changes of solutions being made during the experiment.

After several days it was noticeable that the salicylic aldehyde cultures were developing more slowly. Each of the cultures

seemed affected, regardless of the composition or the proportion of the nutrient salts. The green weight of each culture without salicylic aldehyde is given in Diagram 1 and that of each culture containing the aldehyde in Diagram 2 of Fig. 11. The composition of each of these solutions, as to the ratio of the nutrient salts, can be determined by consulting Fig. 5.

By a comparison of the two diagrams it is seen that the green weights of the set containing the aldehyde are lower in almost every culture than the weights of the corresponding cultures without the aldehyde. The total weight of the 66 cultures without salicylic aldehyde is 149.5 grammes, against 109.7 grammes for

FIG. 11.



Green weight in grammes of wheat plants in nutrient solutions of varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. of salicylic aldehyde.

the set of cultures with 10 parts per million of salicylic aldehyde, a reduction of 27 per cent. in growth.

When these figures are studied according to the composition of the nutrient solution, it is seen that the harmfulness was less in some groups of solutions than in others. There seemed to be a general tendency for more normal development in the cultures in the phosphate end of the triangle. This is brought out well if the weight of all the cultures which contain 50 per cent. and more of P_2O_5 are compared with those which contain 50 per cent. and more of NH_3, or with those which contain 50 per cent. and more of K_2O. All the high phosphate cultures are represented by the triangle marked by the points 1–16–21 of the diagram, Fig. 5. All the high nitrate cultures are represented by the triangle 21–61–66, and the high potash cultures are represented by the

cultures in the triangle 16–61–56. By grouping the cultures thus an average result is obtained with the mainly phosphatic, mainly nitrogenous, and mainly potassic fertilizers. The sum of the 21 cultures in each group is given in Table V.

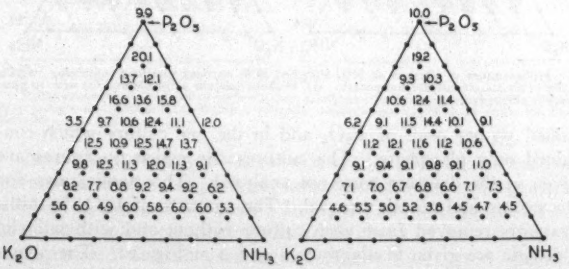
TABLE V.

Total Green Weights of the Mainly Phosphatic, Mainly Nitrogenous, and Mainly Potassic Cultures Without and With 10 Parts per Million Salicylic Aldehyde.

	Without salicylic aldehyde	With salicylic aldehyde	Per cent. decrease in salicylic aldehyde cultures
	Grammes	*Grammes*	
Phosphatic	39.61	31.74	20
Nitrogenous	49.36	36.11	27
Potassic	47.67	33.74	29

A comparison of the green weights shows that salicylic aldehyde reduced growth less in the phosphatic cultures than in the others. In the phosphatic cultures there was a reduction of 20 per cent. in growth, in the nitrogenous 27 per cent., and in the potassic 29 per cent.

FIG. 12.



Milligrammes of P_2O_5 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

Absorption of Nutrient Salts.

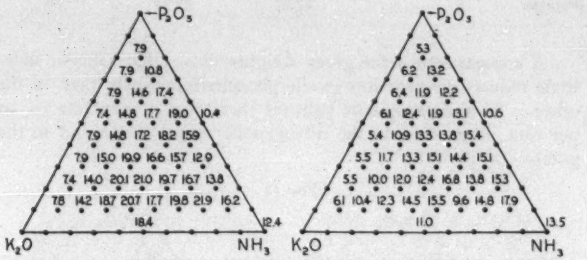
As salicylic aldehyde has been shown to be harmful to growth in culture solutions containing nutrient salts, it will be interesting to study its effect on the removal of nutrients from the solutions during the growth of the plant.

As stated above, the concentration differences produced by

the growth of the plants in the various cultures were determined by making an analysis for nitrates at the termination of every three-day change, and of phosphate and potassium on a composite of the solutions from the four changes. It is possible, therefore, to compare the results obtained in the normal cultures without salicylic aldehyde and in the cultures where 10 parts per million of salicylic aldehyde were present in the solution.

Phosphates.—The absorption of phosphates was determined only in those solutions in which the three constituents were present, as shown in Fig. 12, and in the two cultures which con-

FIG. 13.



Milligrammes of nitrogen as NH_3 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

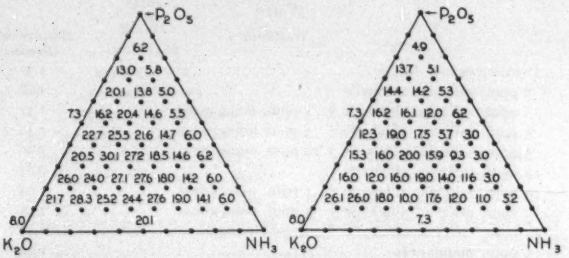
tained 50 per cent. of P_2O_5 and in the one culture which contained only phosphate. The cultures for which no figures are given in the diagram were not analyzed. This applies also for the nitrate and potash removal. The amounts of P_2O_5 in milligrammes removed from each culture without and with salicylic aldehyde are given in diagrams 1 and 2 of Fig. 12. The plants growing in the aldehyde cultures have removed slightly less phosphates than those in the normal cultures. The total absorption from the normal set was 395.7 milligrammes and for the aldehyde set 344.2 milligrammes. The salicylic aldehyde cultures absorbed 51.5 milligrammes less than the normal cultures.

Nitrates.—An examination of the two diagrams of Fig. 13 will show that there was considerable difference of absorption of nitrates between the cultures without and with salicylic aldehyde. The total amounts of nitrate, stated as NH_3, removed from the

total number of cultures analyzed during the course of the experiment were 578.3 milligrammes for the normal cultures and 454.9 milligrammes for the salicylic aldehyde cultures. The aldehyde cultures used 123.4 milligrammes less nitrate.

Potassium.—The amounts of potash, stated as K_2O, absorbed by the plants in the total number of cultures as shown in the diagrams of Fig. 14 were 627.6 milligrammes in the case of the normal cultures and 533.2 milligrammes for the cultures with salicylic aldehyde. As with the phosphate and nitrate, the salicylic aldehyde cultures absorbed less potash, there being a difference of 139.4 milligrammes in favor of the normal cultures.

FIG. 14.



Milligrammes of K_2O absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

From the foregoing results it is seen that salicylic aldehyde in amounts as small as 10 parts per million is harmful to the growth of wheat in nutrient solutions. In regard to the composition of the nutrient solutions affecting the harmfulness of the aldehyde it might be said that an examination of the total green weights obtained in the case of the mainly phosphatic, the mainly nitrogenous, and the mainly potassic cultures shows that the least harmful effects are noted in the phosphatic group of cultures. This group as a whole shows a depression due to salicylic aldehyde of approximately 20 per cent. in growth, while the other two groups showed approximately 27 and 29 per cent. below the respective group of cultures without the aldehyde.

An examination of the above analytical figures shows a more nearly normal absorption of phosphate than of the nitrate or

potash under the influence of the salicylic aldehyde. This would appear to be in harmony with the relatively lessened toxicity of the aldehyde in the mainly phosphatic nutrient solutions.

Effect of Manganese on the Action of Salicylic Aldehyde.

The effect of manganese on the harmfulness of salicylic aldehyde was studied in an experiment growing wheat plants in distilled water. The wheat seedlings were grown in culture jars holding 25 c.c. of pure distilled water. The plants grew for twelve days. The results are given in Table VI.

TABLE VI.

Effect of Manganese Sulphate On the Action of Salicylic Aldehyde in Distilled Water.

Treatment	Green weight *Grammes*
Distilled water	1.37
5 ppm. salicylic aldehyde	1.18
5 ppm. salicylic aldehyde + 1 ppm. manganese	1.32
5 ppm. salicylic aldehyde + 5 ppm. manganese	1.32
5 ppm. salicylic aldehyde + 10 ppm. manganese	1.50
10 ppm. salicylic aldehyde	0.87
10 ppm. salicylic aldehyde + 1 ppm. manganese	1.04
10 ppm. salicylic aldehyde + 5 ppm. manganese	1.57
10 ppm. salicylic aldehyde + 10 ppm. manganese	1.45
1 ppm. manganese	1.42
5 ppm. manganese	1.59
10 ppm. manganese	1.57

As seen from the green weight figures in the table, the salicylic aldehyde was harmful in distilled water in amounts of 5 and 10 parts per million. Manganese sulphate in amounts of 1, 5, and 10 parts per million of manganese overcame the effect of the aldehyde partly with the lower concentration of manganese and entirely with the larger amount.

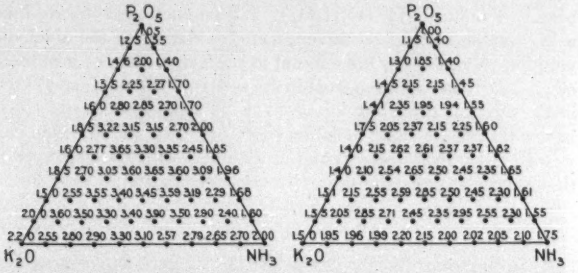
Effect of Calcium Carbonate on the Action of Salicylic Aldehyde.

In order to study the effect of salicylic aldehyde under physiologically alkaline conditions, an experiment was made in nutrient-culture solutions containing calcium carbonate. The experiment was a duplicate of the one with the 66 nutrient solutions just recorded, except that 100 milligrammes of calcium carbonate was added to each culture in both the normal triangle and in the

salicylic aldehyde triangle. Salicylic aldehyde was used in quantities of 10 parts per million. The plants grew from March 23 to April 4—12 days. The solutions were changed every three days. The green weights of the plants grown in solutions without and with salicylic aldehyde are given in the diagrams of Fig. 15.

These data show that salicylic aldehyde was harmful even in nutrient solutions containing an excess of lime. The total green weight of the 66 cultures in the normal set was 171.5 grammes, against 135.3 grammes for the set of cultures with salicylic aldehyde. In this case the growth was depressed 21 per cent. as an average of all the cultures. In the previous experiment, involv-

FIG. 15.



Green weight in grammes of wheat plants in nutrient solutions of varying ratios of phosphate, nitrate and potash with calcium carbonate: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

ing a large number of nutrient solutions without calcium carbonate, growth was reduced 27 per cent. by salicylic aldehyde used in the same concentration. While the aldehyde was harmful in the presence of lime, the experiment indicates somewhat that lime overcomes its effect to a slight degree.

The roots of the plants were not nearly as much stunted in the presence of calcium carbonate as they were in the experiment where no lime carbonate was used. The harmfulness of the aldehyde can in no way be attributed to any slight acidity it may possess.

When the cultures are grouped, as in the former set without lime, according to the composition of the solution, it is seen that salicylic aldehyde reduced growth in the 21 mainly phosphatic solutions (sub-triangle 1–16–21) 12 per cent., in the 21 mainly

nitrogenous solutions (sub-triangle 21–61–66) 20 per cent., and in the 21 mainly potassic solutions (sub-triangle 16–61–56) 25 per cent. The salicylic aldehyde was again less harmful in the solutions with high P_2O_5 content.

The ameliorating effect of high phosphate containing nutrient solutions, together with the relatively high absorption of phosphates, indicates that phosphates have some antitoxic action on the harmfulness of salicylic aldehyde in solution cultures.

Vanillin.

Vanillin, $C_6H_3 \begin{matrix} COH \\ OCH_3 \\ OH \end{matrix}$, is an aromatic aldehyde, methyl protocatechuic aldehyde, and is the aromatic principle of the vanilla bean. Vanillin acid ($C_2H_8O_4$), a monomethyl-protocatechuic acid, may be formed by the energetic oxidation of the aldehyde vanillin. Vanillin has been found in seeds and roots of a number of plants. It has been reported in the seeds and roots of oats (36), in the seeds of the white lupine (12), in asparagus shoots (78), in raw beet sugar (39), in dahlia roots (35, 80), and in rotten oak wood (74). It has been found in a number of soils; its origin is thought to be from the decay of vegetable matter.

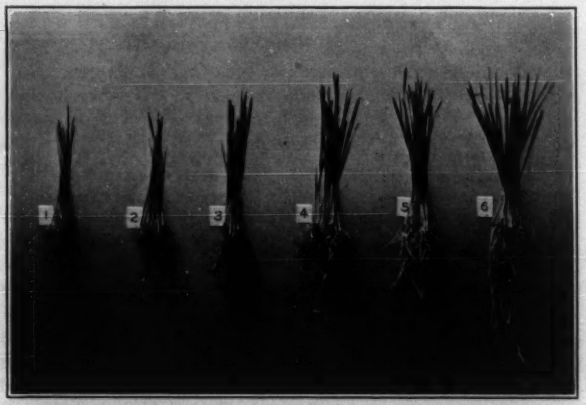
Effect on Growth.

Vanillin, then, has the characteristics of an aldehyde and, like the salicylic aldehyde, is toxic to plants, though to a less degree. Vanillin solutions were shown by Klebs to be fatal to the alga *Conferva minor* (26), and Reed and Williams (37) found that vanillin in 500 and 1000 parts per million reduced the growth and fixation of nitrogen by Azotobacter 28 and 57 per cent. respectively.

It has been found in solution cultures to be toxic to wheat seedlings, 500 parts per million being sufficient to kill. Plant roots are able to oxidize vanillin and become dark as a result of the oxidation. A slight stimulating effect was observed with very weak solutions (43, 52). In Fig. 16 are shown the effects of different concentrations of vanillin in distilled water on wheat plants. The harmfulness of the vanillin in water cultures is here shown, and it can be observed that the roots of plants grown in concentrations greater than 100 parts per million are stained a dark color as a result of the oxidation of the vanillin. The toxic

effects of the vanillin were less marked upon the tops of the wheat plants than upon the roots, nevertheless the green weight of the tops of all the solutions was less than that of the tops of the controlled plants grown in distilled water. Work reported in 1911 shows that vanillin, an oxidizable substance, behaves quite differently in nutrient-solution cultures from quinone, a reducing substance (52, 53).

FIG. 16.



Effect of vanillin in distilled water on wheat seedlings: No. 1, vanillin 1000 ppm.; No. 2, 500 ppm.; No. 3, 100 ppm.; No. 4, 25 ppm.; No. 5, 1 ppm.; No. 6, distilled water.

Effect in Nutrient Solutions with Various Fertilizer Ingredients.

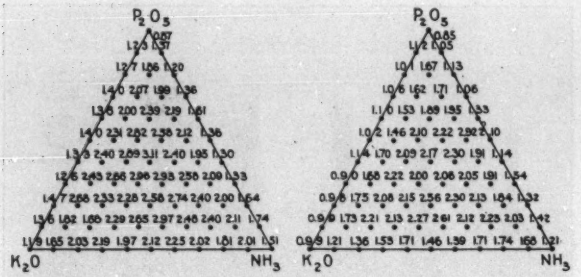
In the experiment with vanillin in nutrient solutions the same number of cultures, 66 containing all the fertilizer combinations possible in 10 per cent. stages, was used as in the experiment with the salicylic aldehyde. The concentration of vanillin used was 50 parts per million. The duration of the experiment was from March 7 to March 19. The solutions were changed every three days, as in the salicylic aldehyde experiment already described, but no analyses of the solutions were made in this case. The green weights were, however, recorded, and are given for each culture in the diagrams of Fig. 17.

The effect of the vanillin was not so marked on the tops as on

the roots, although in the region of better growth this also was not very prominent. The effect, even with 50 parts per million, was not so harmful as salicylic aldehyde. The region of greatest growth appeared to be shifted toward the nitrogen end of the triangle.

The total growth in the normal set of cultures was 133.5 grammes, against 111.5 grammes for the set of cultures containing the vanillin. This is a reduction of 26 per cent. The growth in the cultures respectively high in phosphate, nitrate, or potash is of paramount interest. This grouping of the cultures as explained in the salicylic experiment is shown in Table VII.

FIG. 17.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without vanillin and (2) with 50 ppm. of vanillin.

TABLE VII.

Total Green Weight of the Mainly Phosphatic, Mainly Nitrogenous, and Mainly Potassic Cultures, Without and With 50 Parts Per Million of Vanillin.

Culture solutions	Without vanillin	With vanillin	Per cent. decrease in vanillin cultures
	Grammes	*Grammes*	
Phosphatic	37.8	31.9	15
Nitrogenous	42.8	37.8	12
Potassic	40.7	33.2	18

It will be observed that vanillin depressed growth least in the cultures high in nitrate, a result which is in harmony with previous observations on the toxicity of vanillin and its behavior with nitrate.

Vanillin has reducing properties; that is, it is readily oxidized.

It has an inhibiting effect on root oxidation and on root growth in general. Sodium nitrate and calcium carbonates, which promote oxidation in plants and soils, ameliorate the harmfulness of vanillin. The action of fertilizers on the two aldehydes thus far reported is quite different. The harmful effects of salicylic aldehyde in nutrient solutions are lessened by phosphates, and the harmfulness of vanillin in nutrient solution is lessened by sodium nitrate.

THE EFFECT ON COWPEAS IN NUTRIENT SOLUTIONS OF DIFFERENT COMPOSITIONS.

An experiment growing cowpeas in nutrient solutions was made in which the effect of vanillin was studied. The solutions were composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, used singly and in combinations. It was found that in some of these nutrient solutions the vanillin was more harmful than in others. Culture jars holding 250 c.c. of solution were used, and two cowpea plants were grown in each jar. The plants were germinated in sand, and when about 1 inch high were put in the nutrient solution. The culture solutions, as stated above, were composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, in amount of 80 parts per million total of P_2O_5, NH_3, and K_2O. These solutions were changed every fifth day; the old solutions were replaced by new four times during the experiment. They were analyzed to determine the amount of phosphate, nitrate, and potash removed by plants. In this way the effect of vanillin on the metabolism of plants was studied. The peas grew for 21 days, from June 17 to July 8. The results are given in Table VIII. The composition of the culture solutions is given in the second, third, and fourth columns. The green weights of the plants grown in the solutions without vanillin are given in the fifth column, and with 100 parts per million of vanillin in the sixth column. The absorption of the nutrient salts is given in the remainder of the table.

The green weight was reduced by the vanillin in each culture except No. 5. When the cultures are grouped as in the table, according to their composition, it is seen that the vanillin is least harmful in those cultures which are composed principally of nitrates. Cultures Nos. 1 to 4 are composed principally of phosphate; Nos. 5 to 8 principally of nitrates, and Nos. 9 to 12 prin-

TABLE VIII.

Growth of Cowpeas in Nutrient Solution With and Without Vanillin (100 p.p.m.). June 17 to July 8.

No.	Composition of culture solution			Green weight of cultures		Nutrient absorbed					
						P_2O_5		NO_3 stated as NH_3		K_2O	
	P_2O_5	NH_3	K_2O	without vanillin	with vanillin	without vanillin	with vanillin	without vanillin	with vanillin	without vanillin	with vanillin
	p.p.m	*p.p.m.*	*p.p.m.*	*grams*	*grams*	*m.g.*	*m.g.*	*m.g.*	*m.g.*	*m.g.*	*m.g.*
1	80	0	0	1.37	1.10	16.0	13.2	.....	.....	.....	.....
2	64	8	8	3.57	2.50	15.3	13.1	8.0	7.5	4.9	4.0
3	48	16	16	4.87	3.97	12.1	7.3	12.2	8.9	12.2	6.4
4	32	24	24	5.37	3.55	10.7	7.1	14.6	13.2	17.5	17.5
				15.18	11.12						
5	0	80	0	2.20	2.70	....	....	25.5	24.6	.....	.....
6	8	64	8	3.52	3.40	1.8	0.6	15.3	14.6	3.5	2.3
7	16	48	16	5.02	4.95	3.4	3.4	12.9	10.8	12.0	8.0
8	24	32	24	4.55	4.30	10.4	7.9	17.4	13.1	12.0	15.0
				15.29	15.35						
9	0	0	80	1.85	0.80	....	....	.....	.....	30.2	8.0
10	8	8	64	4.67	4.05	2.1	3.8	8.0	7.7	25.6	23.0
11	16	16	48	5.47	3.70	3.8	4.5	12.1	11.8	24.0	19.0
12	24	24	32	5.95	3.00	8.7	5.3	16.3	10.8	28.5	11.0
				17.94	11.55						
Total				48.41	38.12	88.3	66.2	142.3	129.0	170.4	114.7
Per cent. decrease in vanillin culture					21		21		10		33

cipally of potassium. The total green weight of the high phosphate cultures (Nos. 1 to 4) was 15.18 grammes in the solutions without vanillin and 11.12 grammes with vanillin. In the high nitrate cultures (Nos. 5 to 8) the weight without vanillin was 15.29 grammes, against 15.35 grammes for the cultures with vanillin. In the high potash cultures (Nos. 9 to 12) the weight without vanillin was 17.94 grammes, against 11.55 grammes for the cultures with vanillin. It is apparent that in the solution composed principally of nitrate the vanillin had practically no effect, and in culture No. 5, composed of all nitrate, the growth in the vanillin culture was larger than in its control.

The absorption of salts was also less from the solutions containing vanillin than from their controls without vanillin. The absorption of each nutrient element for each culture is given in the table. Considering all the cultures, the phosphate absorption was reduced 21 per cent., the nitrate 10 per cent., and the potash 33 per cent. The absorption of nitrate was less interfered with by the vanillin than either phosphate or potassium.

The results with cowpeas are in harmony with those with wheat seedlings, where it was shown that the harmfulness of vanillin was very slight in solutions high in nitrate content, and that its effect was less in cultures composed principally of nitrate than in cultures composed principally of phosphate or potassium (52, 53). The roots of plants have an oxidizing power, which is increased by nitrate fertilizers (45). Vanillin is changed or even destroyed by oxidation. This compound, when used in nutrient solutions containing a high percentage of nitrates, is probably changed, and does not remain as such to have its effect on plant growth.

Effect of Manganese on the Physiological Action of Vanillin.

The effects of manganese on the harmfulness of vanillin were studied in an experiment growing wheat plants in distilled water. The wheat seedlings were grown in culture jars holding 250 c.c. of pure distilled water. Manganese sulphate was used in amounts of 1 and 5 parts per million of manganese. The plants grew 12 days. The results are given in Table IX.

TABLE IX.

Effect of Manganese Sulphate On the Harmful Action of Vanillin in Distilled Water.

Treatment	Green weights *Grammes*
Distilled water	2.18
100 ppm. vanillin	1.60
100 ppm. vanillin + 1 ppm. manganese	2.03
100 ppm. vanillin + 5 ppm. manganese	1.90
1 ppm. manganese	2.20
5 ppm. manganese	2.24

The harmful effect of vanillin was here partly overcome by manganese used in small amounts. The oxidizing power of the plant roots was determined in the different culture solutions by the method described in Bulletin 56, Bureau of Soils (45), and Bulletin 42 of the U. S. Department of Agriculture (71). The oxidation was lessened in the vanillin culture, but was increased in the solution where manganese was used, which is in harmony with the growth in these solutions.

Manganese increases the oxidizing power of plants in certain soil extracts (59), as well as increases the oxidation of certain soils.

In a later section of this paper are given experiments bearing on the effect of manganese in soils to which vanillin and salicylic aldehyde were added. It is there shown that manganese destroyed the effects of these aldehydes to a certain extent. All these results point to the fact that manganese, through stimulating oxidation, can aid in the destruction of such harmful organic substances as aldehydes capable of ready oxidation.

BENZALDEHYDE.

Benzaldehyde, C_6H_5-COH (oil of bitter almonds), is formed, together with glucose and hydrocyanic acid, by the decomposition of amygdalin, a glucoside which is found in bitter almonds, peach-stones, and several other vegetable substances. Benzaldehyde oxidizes readily to benzoic acid, C_6H_5COOH, and unites with hydrogen to form benzyl alcohol, $C_6H_5CH_2OH$. The relations between the three substances are like those between any primary alcohol and the corresponding aldehyde and acid, as shown by the formulas:

$C_6H_5.CH_2OH$;	$C_6H_5.COH$;	$C_6H_5.COOH$
Benzyl alcohol	Benzoic aldehyde	Benzoic acid

Effect on Growth in Nutrient Solutions with Various Fertilizer Ingredients.

The experiments with benzaldehyde in nutrient-culture solutions showed it to be very harmful to wheat plants in relatively small amounts. A complete triangle set of solutions, composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, used singly and in combinations of two and three salts in 10 per cent. stages, as already described, was used. In this experiment the benzaldehyde was used in concentrations of 25 parts per million. Four changes of solutions were made during the experiment. The plants grew in the solutions from February 17 to March 1, 1916. The green weights of the individual cultures are given in the diagram of Fig. 18.

It is seen, by comparing the weights of the cultures without the aldehyde with the corresponding culture which contains the aldehyde, that in every case except one the aldehyde culture is smaller.

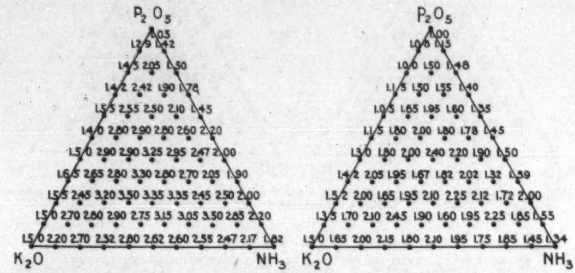
The total weight of the entire set of cultures in the triangle without benzaldehyde was 163.2 grammes, against 113.0 grammes

for the set with 25 parts per million of benzaldehyde. This is a reduction of 30 per cent. in growth.

When the solutions are grouped according to their composition, it is seen that the 21 mainly phosphatic cultures—that is, those within the triangle marked by the points 1–16–21, Fig. 5—produced as a total 41.1 grammes green weight for the normal set and 30.5 grammes green weight for the benzaldehyde set, a reduction of 26 per cent.

The mainly nitrogenous cultures—that is, those solutions within the triangle marked by the points 21–61–66—produced

FIG. 18.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

52.5 grammes green weight in the normal set and 37.5 grammes in the benzaldehyde set, a reduction of 29 per cent.

The mainly potassic cultures—those solutions within the triangle marked by the points 16–61–56—produced 50.5 grammes green weight in the normal culture and 37.5 grammes in the benzaldehyde cultures, a reduction of 25 per cent.

The depression of growth by benzaldehyde in the mainly phosphatic solutions and mainly potassic solutions was practically the same—in the former growth was depressed 26 per cent. and in the latter 25 per cent. The aldehyde was, however, somewhat more harmful in the highly nitrogenous solutions; in this case growth was reduced 29 per cent.

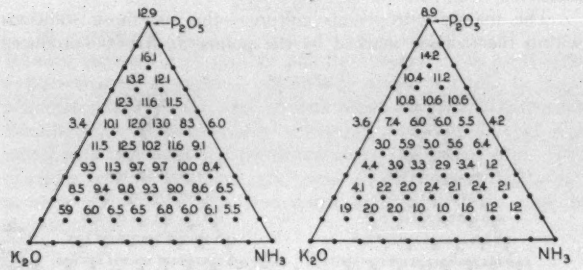
A second experiment with benzaldehyde in a complete set of nutrient solutions was made, in which the aldehyde was used in concentrations of 50 parts per million. With this concentration

the aldehyde proved extremely harmful. There was an average reduction of all the solutions of 53 per cent.

Absorption of Nutrient Salts.

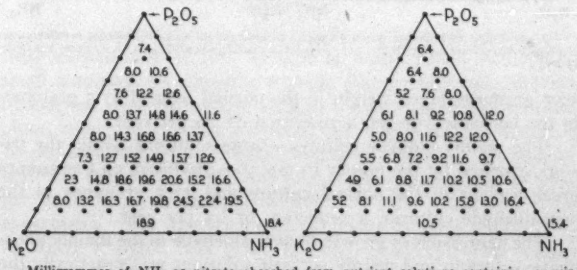
Phosphates.—The absorption of phosphates was much less in the 25 ppm. benzaldehyde set than in the normal set of cultures.

FIG. 19.



Milligrammes of P_2O_5 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

FIG. 20.



Milligrammes of NH_3 as nitrate absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

The amount, expressed in milligrammes, of P_2O_5 absorbed from each solution analyzed is given in the diagram of Fig. 19.

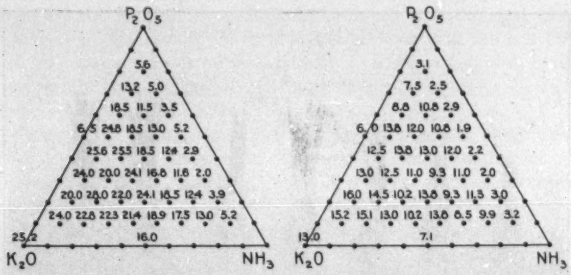
The total amount of P_2O_5 absorbed by the set of normal cultures was 366.2 milligrammes, and by the benzaldehyde cultures only 183.6 milligrammes, a reduction of 50 per cent.

Nitrates.—The absorption of nitrates was also less in the benzaldehyde cultures than in the normal cultures. This is true of almost every corresponding culture of the two sets, as will be shown by examining the diagrams of Fig. 20, which gives the absorption of each culture.

The normal set of cultures removed 574.5 milligrammes of NH_3 as nitrate, and the benzaldehyde set 364.1 milligrammes, which is a reduction of 37 per cent.

Potassium.—As with the phosphates and nitrates, there was also less potash removed from the benzaldehyde set of solutions than from the normal set. The percentage decrease, however,

FIG. 21.



Milligrammes of K_2O absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

was not quite so large. The absorption of each culture analyzed is given in the diagram of Fig. 21. The normal set of solutions absorbed a total of 378.7 milligrammes of K_2O, and the benzaldehyde set a total of 379.4 milligrammes. This is a reduction of 35 per cent.

The phosphate absorption was reduced 50 per cent. by benzaldehyde, the nitrate 37 per cent., and the potash 35 per cent. Thus it is seen that the absorption of potash is more normal than that of phosphate, and slightly more so than that of nitrates. In this connection it is interesting to note that the growth was slightly more normal in the mainly potassic solutions. The differences, though slight, indicate that potassium alters somewhat the physiological effect of this aldehyde.

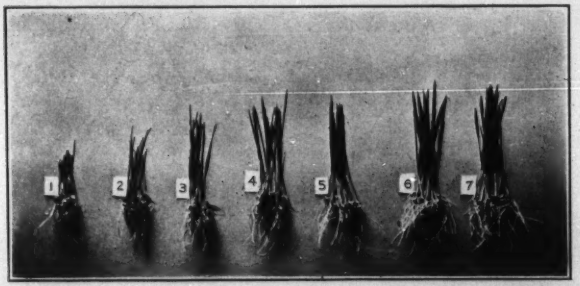
HELIOTROPINE.

Heliotropine or piperonal, $C_6H_3 \begin{cases} CHO \\ O \\ O \end{cases} > CH_2$ is the aldehyde of piperonylic acid. It possesses the odor of heliotrope and is found in the flowers of *Nigritella suaveolens* (78). It has not specifically been found as a soil constituent.

Effect on Growth.

Heliotropine was found to affect the growth of wheat plants in distilled water very markedly. The tops of the plants were affected more than the roots. The effect of this aldehyde on wheat plants is shown in Fig. 22. Here it is seen that the roots are

FIG. 22.



Effect of heliotropine in distilled water on wheat seedlings: No. 1, heliotropine 1000 ppm.; No. 2, 500 ppm.; No. 3, 100 ppm.; No. 4, 25 ppm.; No. 5, 10 ppm.; No. 6, 1 ppm.; No. 7, distilled water.

almost normal, even in the highest concentration, while the tops are much reduced in growth in a concentration of 25 parts per million.

Effect in Solutions with Various Fertilizer Ingredients.

The effect of the heliotropine on wheat seedlings was also studied in nutrient culture solutions, in which the triangular system of 66 solutions was used. The heliotropine was used in concentrations of 25 parts per million. The details of the experiments were the same as those described in the experiment with salicylic aldehyde and vanillin. The experiment was conducted from May 15 to May 27, 1916; four changes of solutions were made.

(*To be Continued.*)

ON THE LUMINESCENCE DUE TO RADIO-ACTIVITY.*

BY

ENOCH KARRER, Ph.D.,

Physicist, Research Department, United Gas Improvement Company,
Member of the Institute,

AND

D. H. KABAKJIAN, Ph.D.,

Assistant Professor of Physics, University of Pennsylvania.

THE luminescence produced by irradiating zinc sulphide and other substances with the rays from radio-active compounds has long been an object of interest. However, quantitative measurement of the brightness with such luminescent bodies has very rarely been made, and, in fact, it has been only in the last two or three years that definite quantitative comparisons were made between the so-called self-luminous paints that are now extensively employed for various military purposes.

In case of the self-luminous zinc sulphide paints, the brightness depends upon the amount of the radium elements present per gramme of the zinc sulphide. This is true for a given specimen of zinc sulphide and a given mode of treatment of it. For the intensity of luminescence attained is likewise dependent to a very great degree upon the purity of the zinc sulphide and upon its treatment. We have found this to be the case also with the specimens of self-luminous materials, some of whose characteristics are described below.

It is well known that the self-luminous substances that are commonly obtained on the market under the name of radium paints have a definite life. The brightness of them decreases with age, due not alone to the fact that all radio-active elements are decaying, but chiefly due to the fact that the zinc sulphide changes its form, so that it ceases to give the same intensity of light for the same intensity of stimulus.

In case of all the self-luminous paints containing any one of a number of radio-active elements, it is the α-rays which cause the emission of most of the light. In some of these compounds the light caused to be emitted by a single α-ray may be seen. The

* Communicated by Doctor Karrer.

classical illustration of this is in the Crookes spinthariscope, where polonium or radium is the source of α-particles and zinc sulphide is the luminescent substance viewed with a lens. We have found a large number of substances which show the scintillations plainly. In the substances described below these scintillations are easily seen when the material has been properly prepared.

After the luminescence of zinc sulphide has been decreased by age there is no known simple operation which will rejuvenate it, so that it may continue to luminesce throughout the life of the radio-active element.

Radium bromide, however, can be rejuvenated by heating. The fact that radium salts that are luminous may be rejuvenated by recrystallization when their luminosity has decreased has been known for some time and holds for all radio-active salts, and also that such salts become non-luminous when allowed to absorb moisture from the air and become luminous again when dried out. In case of autunite, drying seems to decrease the luminosity.

It has been known for some time that certain salts, such as barium platinocyanide, may be somewhat revived by heating when allowed to become exhausted under α-ray bombardment. The fact that radium bromide is so markedly rejuvenated by heating alone was independently observed by one of us.[1]

No quantitative data have been placed upon record such as we have attempted to give in this paper, where we purpose to describe some of these properties of self-luminous materials and, in particular, of radium bromide, which exhibits them very markedly.

Freshly prepared radium bromide is feebly luminous while in the solution, becoming more luminous after removal from the liquid and after drying by gentle heating. A tube of radium bromide so prepared will decrease in brightness with time, as self-luminous materials are wont to do, and if it contains a large amount of radium it will have decreased materially in brightness in a few days or even hours.

Then let us heat the tube by resting it upon an iron plate supported over a Bunsen flame. The tube will momentarily remain of the same brightness, so far as one can judge—probably actually decrease for a moment—then it will very suddenly flash up to a brightness sometimes comparable to its original brightness.

[1] D. H. Kabakjian, paper before the Physics Faculty, May, 1917.

This flash is very momentary, and the brightness steadily and rapidly decreases thereafter until the tube is no longer luminous. The time which elapses between the commencement of the flashing to total decay is dependent upon the rate of heating to the necessary temperature. In our small tubes it was only a matter of a few seconds.

If now the tube be allowed to cool to room temperature, it will again become luminous with a brightness gradually increasing until room temperature is reached. If the tube be allowed to remain at room temperature, its brightness will have again materially decreased after several days, when the same cycle may be gone through again. These operations may be repeated indefinitely, so far as our experience with these tubes shows. There is at present no evidence that the end-products, for instance, of the decomposition of the radio-active element itself can materially affect the property to luminesce.

After heating, the salt is white in reflected sunlight, with only a trace of the yellowish tint. In time this color changes to a dark, almost black, having in it a bluish or purplish tint, due to the discoloration of the glass. In several tubes we have had very slight evidence that the granularity of the salt also changes.

The discoloring of the substance and behavior after heating indicate that the property to luminesce is dependent upon some molecular structure of the salt, and that, due to the process of radiating energy or incident to this manner of stimulus, this structure is destroyed.

The light emitted by the substance turns more greenish-blue with age, being quite white initially. We have now in progress experiments which will elucidate these changes in the spectral distribution of the energy, and elucidate somewhat the phenomenon of flashing up and of the discoloration of the salts and of the glass. The data will be given in a paper in the near future.

Though these are the salient and most obvious features regarding the spectrum of these substances, there are certain other very fleeting variations in the color of the light. During the flashing up the color becomes a very yellowish, then changes more green. On cooling, also, a similar variation takes place. A very yellowish hue changes into a bluish, and subsequently more and more white with decrease of temperature. Sometimes several flashes may occur on heating. This flashing up affords an

admirable way to show the propagation of a heat wave through a solid.

Naturally it is of interest to inquire how these substances would behave at a temperature below room temperature. We have as yet only qualitative data to present on this point. However, lowering of the temperature below normal room temperatures does not have so striking effects as described above for higher temperatures.

If a tube of radium barium bromide which has been previously heated to a temperature of 400–500° C. is immersed in liquid air, the brightness of the salt undergoes probably a slight decrease, but otherwise no change is observed. If, after remaining in the liquid air for a few minutes, the tube is taken out and allowed to reach the room temperature gradually, the salt remains at its original degree of brightness for a few seconds, then suddenly it flashes up, reaching a brightness many times the original brightness, followed by a quick fall to a level below the original brightness. A repetition of this phenomenon may take place on a smaller scale before the tube reaches equilibrium. Three such successive oscillations with constantly decreasing amplitudes have been observed under favorable conditions.

These observations we hope to repeat quantitatively.

The phenomenon of flashing up is undoubtedly connected with the phenomenon of thermo-luminescence which glass shows after having been subjected to the rays from radium. However, two flashings have not been observed by us in glass alone, a large number of specimens of which have been examined in this respect. The flashing appears just below temperature of dull red iron. The discoloration also begins to disappear at about the same temperature. At dull red heat the purple discoloration, even though very intense, will disappear in a few minutes. A thick capillary tube which had been very much discolored became clear after heating for about 15 minutes at 250° C. The discoloration is not essential to the phenomenon of flashing. In fact, the intensity or quantity of the flash seems in some cases to be quite independent of the degree of discoloration. Fused quartz will show thermo-luminescence when there are no indications whatever of discoloration.

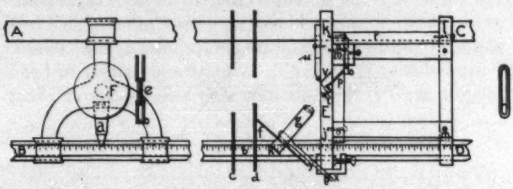
The experimental set-up is shown in Fig. 1, where a horizontal sectional view is represented of a photometer bar equipped for the

present investigation. *AC* and *BD* are bars upon which the carrier for the reference lamp *F* is mounted. The rays of light from the lamp *F* fall upon a celluloid card *t*, which is pierced with a small hole *w*, about 1 mm. in diameter, through which the luminescent surface *s* may be viewed. The card *t* and the luminescent surface *s* are observed through the telescope *g*, magnifying about two and one-half times.

The card of celluloid *t* is mounted upon an upright board *E*, half of which has been cut away, and the half *vk* remains. This board is held secure by a frame *jmlk* with a brace at *r*; *p* and *o* are adjustable rods to support the tube *s*. The tube is shown in Fig. 2 (3 mm. × 18 mm.).

c, *d*, and *f* are screens; *e* the color screen, attached to the carrier for the lamp and very close to the lamp. The position of

FIGS. 1 AND 2.



Photometrical set-up for comparing brightness of luminescent substances, and, at extreme right, tube containing radium salt.

the lamp is read by means of the index *a* on scale *b*. The lamp is a point-source tungsten (100-watt, 110-volt). The intensity of the light falling upon the screen *t* is calculated from the inverse square relation. This was tested for our lamp when supplied with the screens used.

The manner of mounting the tubes under observation and the relative position of them are shown in an enlarged view of Fig. 3. The tube *s* was attached in a groove in the end of the rod *p* by means of soft wax. No rays direct from the standard lamp can fall upon the tube. This point is particularly important when self-luminous paints containing zinc sulphide are observed. The effects of an exposure may last longer than a day. Radium bromide is not sensitive to ordinary light.

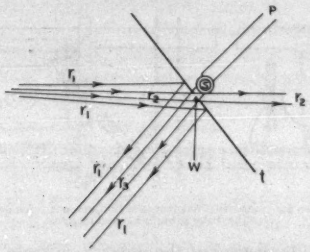
The perforation at *w* in the celluloid card could preferably be made larger. It was adapted in the present case to the small

samples of the radium salts available. The celluloid disc was coated with magnesia oxide. Its coefficient of reflection was 70.9 per cent. This was determined by means of an illuminometer mounted in the place of the observing telescope *g*.

The samples of radium bromide and of radium chloride were freshly prepared and sealed. In most instances the observations were made within the first three weeks after preparation.

The luminescent materials to which the curves refer were of unknown concentrations. The amount of them was in every case very minute and in some instances adhering to the glass walls, so that determination of the percentage of radium would be very difficult. Knowing the history of these preparations, however, we can state the approximate composition in the description of them.

FIG. 3.



Celluloid disc and manner of placing tube.

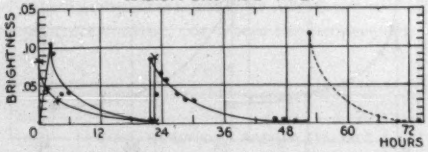
The tubes which are associated with the curves, Figs. 4, 5, 6, 7, and 8, were heated merely by resting them upon an iron plate heated by a Bunsen flame to a very dull red.

In the majority of cases the slopes of the curves are not intended to represent the rate of decay of luminescence accurately. Only in cases where a sufficient number of observations were taken can the curve be relied upon, such as the two in Fig. 4. All observations or means of several observations are indicated in the curves. One of the objects of this work was to ascertain whether the materials could be repeatedly subjected to heating and maintain something like the initial brightness. The curves show that there is some uniformity, as much as we may expect, under the crudely controlled conditions under which these experiments were

performed. It is the last series of materials recorded in this paper that we are observing under more accurately controlled conditions.

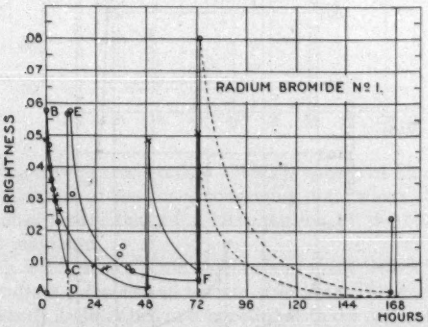
In Fig. 4 are plotted the observations on a tube containing radium bromide and barium bromide. The radium constituted about 30 per cent. of this material. The decay of its brightness was very rapid. The curve with the crosses was obtained soon

FIG. 4.



after the preparation of the salt, while the curve with the dots was obtained fourteen days after the last observation on the curve with the crosses was made. This sample of radium bromide was contained in a small quartz tube. The quartz tube became brittle and easily broke, so that observations with it were stopped. If

FIG. 5.



the ordinates are divided by 40 they represent approximately millilamberts.

In Fig. 5 a similar series of observations is recorded for a preparation having a concentration of probably one-half that of the previous tube. The crosses denote observations made soon

after the preparation of the tube, while the circles denote observations begun after fourteen days had elapsed since the last observa-

FIG. 6.

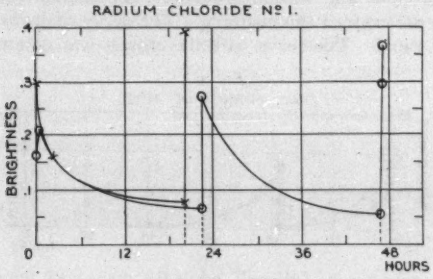
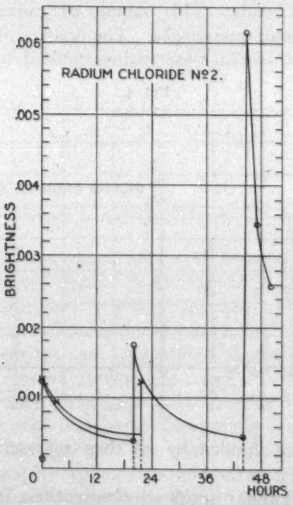


FIG. 7.



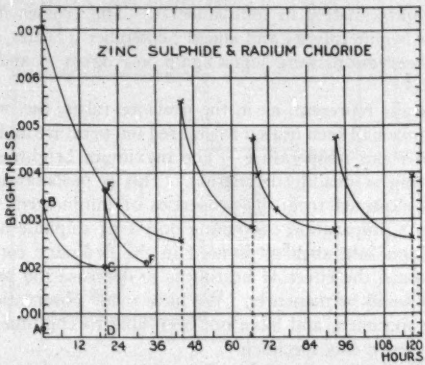
tion marked by a cross had been made. The last observation is lower than the similar observation after heating, because the heat-

ing in this case was only to 221° C., while the previous heatings were to a temperature of a dull red heat. The marked effect of temperature is shown here. Divide ordinates by 2 for millilamberts.

In the curves of Figs. 4 and 5 there are indications that the intensity of the luminescence immediately after heating is increasing, due to the growth of the radio-active products from the radium.

In general, the rate of decay increases on this account also. There are some discrepancies, however, which are probably due to lack of temperature control; for where the temperature is low the

FIG. 8.



slope of the curve is too gradual. This is shown in Fig. 4 by the second maximum of the curve connecting dots, where the curvature is more nearly that of a later portion of the curve after the third maximum.

In Fig. 6 are drawn some observations made with a tube containing radium chloride and barium chloride. The phenomenon here is exactly as described in connection with the previous figures.

The observations were begun about one week after the tube had been sealed. The observations marked with crosses were begun on July 31, 2.30 P.M.; those marked with circles were begun on August 21, 2.30 P.M.

The glass screen (screen No. 1) used to give an approximate

color match in the photometric field was a high transmission green of the Corning Glass Company. Divide ordinates by 50 to have millilamberts approximately.

In Fig. 7 the behavior of a second sample of radium chloride is depicted. This was contained in a small quartz tube. The observations marked with crosses were begun August 3, 1.14 P.M., while those marked with circles were begun August 21, 1.59 P.M. The brightness is in millilamberts approximately. The gradual increase in the maximum here is very marked. The last maximum is probably due to heating to a higher temperature.

In Fig. 8 is shown the behavior of a tube containing radium chloride with which has been mixed zinc sulphide. The brightness here is approximately in millilamberts. The crosses mark observations begun July 24 and ended September 4; after an interruption observations were begun again on August 21 and marked with circles.

The peaks represent, as in the previous tubes, the brightness after the tube had been heated to dull red temperature and allowed to cool to room temperature. The maximum brightness given after heating is steadily decreasing. This is probably not what was to be expected from the properties of luminescent zinc sulphide. In a preparation containing only zinc sulphide and some other radium salt, such as is used in the ordinary commercial radium paints, the effect of heating is to decrease the brightness appreciably and permanently. We have made observations only upon one specimen, and have not been able to continue our observations upon this specimen.

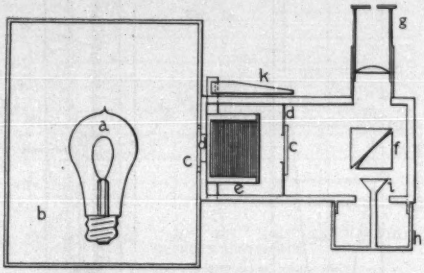
The observations upon the effect of heating on zinc sulphide when stimulated by α-rays were not made with the photometric set-up, so that we can only say that heating to dull red heat or more does decrease the brightness. It may be that the gradual decrease in the maxima of the curve after successive heating is due to the added time interval of heating. The tube was small and the length of time during which it was in contact with the dull red plate was short. The decrease is dependent upon the aggregate time of heating.

It is proper here to remark that one purpose of this investigation was to see whether the self-luminous materials could not be utilized as a standard light-source in pyrometry and illuminometry, thereby making the pyrometer and illuminometer much

more portable, for the standard lamp, together with the necessary batteries and electrical measuring instruments, constitutes the bulk of these instruments. Accordingly, samples of various grades of commercial radium paint were obtained from the following manufacturers: Denver Cold Light Company, the Standard Chemical Company, Radium Luminous Materials Corporation, and Cummings Chemical Company.

The following compact photometer (Fig. 9) was made use of in comparing these samples: The standard lamp *a* is a tungsten filament lamp mounted in a tin box *b*. On one side of the box is constructed a chamber for a neutral-tint absorbing screen *e*, for diffusing screens *c* and diaphragms *d;* together with a pair of

FIG. 9.



Compact photometer.

Lumner Brodhun prisms *f*, a support for the luminous material *i*, and an observing telescope *g*. The luminous material may be readily inserted by removing cap *h*.

The intensity of the light from the standard lamp was varied by means of the screen *e*. The use of the screen *e* eliminated the necessity for a long photometer bar, which was not available for this work at that time. This screen has been recently described by one of us.[2]

The zinc sulphide preparations on the market did not present such prospects of fulfilling our demands as did other radio-active luminous compounds, nor did they offer such interesting data as regards the mechanism of the light-production by radio-active

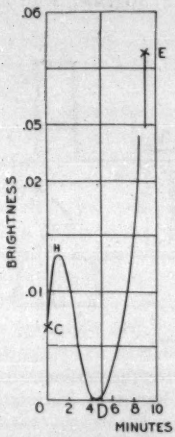
[2] JOURNAL OF THE FRANKLIN INSTITUTE, vol. 185, p. 539, April, 1918.

materials. For these reasons observations on them were discontinued.

For the small amounts of the materials in small, narrow tubes the photometric field in this set-up was not suitable.

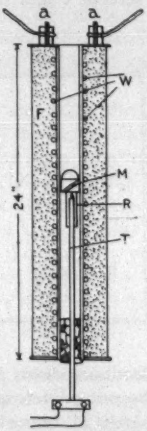
In most of the curves the points of minimum brightness have been connected by dotted lines to the time axis. At these points the material was heated. During the heating there is a very bright momentary flash, as noted above. After this flashing the material gradually becomes less luminous until it is no longer distinguishable from the dull red plate, and its own light is almost,

FIG. 10.



Flashing effect of heating. Brightness *vs.* time.

FIG. 11.



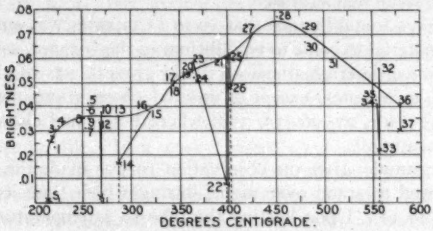
Furnace.

if not entirely, extinguished. The time required for this to take place depends upon the rate of heating, but at most is only a few minutes, so that it cannot be shown with any clearness upon the charts.

In Fig. 10, however, is an exaggerated view of this portion of the curve to show what takes place. For the sake of definiteness the lettering in Fig. 10 refers to corresponding points in Figs. 5 and 8. If we consider a specimen of luminous material which has been freshly prepared or has been kept for some time

at ordinary temperatures, its brightness may be represented by some point *A*. After heating and allowing to come to room temperature its brightness is represented by *B*. The brightness steadily decreases, and after an interval of time, represented along the axis of abscissæ, will have decreased to a value represented by *C*. At this point the material is heated, and we refer to Fig. 10 to see its behavior. A sudden rise in brightness occurs (*CH*), so that temporarily the material may have a brightness comparable with its brightness at any other moment of its history. This brightness rapidly decreases to a minimum value approaching zero, *D*. Now when the material is again allowed to assume room temperature its brightness increases according to the curve *DE*. After some interval of time the brightness will again have fallen to a value *F* and the same operations repeated.

FIG. 12.



Effect of heating. Brightness *vs.* temperature.

The curve *CHDE* of Fig. 10 is only qualitative. It is very difficult to obtain absolute values during this short interval of time of the rapidly varying luminescence.

Having seen the importance of temperature upon the luminescence in these preliminary experiments, we conducted experiments for the purpose of gaining more accurate knowledge of this relationship.

An electric furnace *F* was equipped with a base metal thermocouple *T*, accurately calibrated, as shown in Fig. 11.

The radio-active material was placed in a small iron receptacle *R*, which was adapted to fit snugly over the end of the thermocouple and did not touch the walls of the furnace. The receptacle *R* was removed from the furnace by means of an iron hooked rod. The tube containing the luminescent material was removed

from the receptacle by means of tweezers and laid upon an asbestos pad, where it was allowed to cool to room temperature.

The sample of material used for these observations was radium bromide No. 1, whose decay characteristics have been described in Fig. 5 above.

Referring to Fig. 12, where these observations are shown in a curve, s is the brightness of the material after having been kept at room temperature for several days after the last observation shown in Fig. 5 was made. After heating this tube to 220° C. in the furnace, its brightness was increased to a value represented by point 1. Other points near this temperature we obtained and plotted as 2, 3, and 4. Every point marked in consecutive order represents a determination of the brightness of this tube (in millilamberts) after having been heated in the furnace to a temperature corresponding to the abscissa of the point, and allowed to cool to room temperature.

We have found by trial that 10 to 15 minutes was ample time for the material to come to equilibrium in the furnace, so that the time between determinations of the brightness was of the order of 20 to 30 minutes, except in case of observations marked by crosses (11, 14, 22, 26, 33, 37), where hours had elapsed since the last heating.

For example, after the observation 10 was made the material was allowed to stand over night, during which time its brightness fell to 11. Upon heating the tube to a temperature corresponding very closely to 10, the brightness rose to 12. Between observations 13 and 14 several hours in the midday elapsed, while the brightness rose to 15 and 16 subsequent to heating to a temperature of 320° C. Between observations 21 and 22 is the interval of one night; after heating to a temperature corresponding to observations 19 and 20, points 23 and 24 are obtained; while when heated to a temperature corresponding to point 21, which is the last observation made on the previous day point, 25 is obtained. The sequence of observations at higher temperatures is given by the remaining numbered points.

The tube shows a maximum brightness when heated under these conditions to about 450° C. There is suggested here a means of estimating the temperature of small, inaccessible spaces.

The light given out by these luminescent materials stimulated by α-rays differs very markedly. The zinc sulphide preparations

have a yellowish-green hue; willemite gives a very bright green hue; calcium tungstate has a bluish-green tint; cadmium phosphate a decided red color. Calcium sulphide is very similar to willemite; its phosphorescence, however, is very persistent; calcium salicylate is similar to calcium tungstate. Scintillations may be seen in all of these, and are particularly distinct in zinc and calcium sulphides and in willemite. When the substance is held close to the eye the scintillations may be seen without a lens.

We have prepared tubes containing radium chloride, bromide, and iodide. The luminescence of the iodide is very noticeably orange, while that of the chloride is more greenish-blue than the bromide. There seems here a distinct relationship between the atomic weight and the quality of luminescence produced.

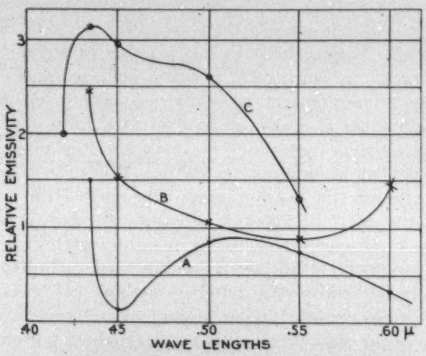
Even in the same sample the color will vary with the age of the material. The brightest of our samples of radium bromide appear very white, but become decided blue and bluish-green as they decay. The preparations containing larger percentages of radio-active material appear more blue than those with smaller percentages. In all these cases, however, the Purkinje phenomenon is probably a most important factor. When the materials are observed in a tube the discoloration of the walls of the tube plays an important rôle. In a work [3] recently published the effects of discoloration were corrected for by separate determinations. In the observations recorded below the effects of such discoloration were eliminated entirely by another method. However, in all the observations recorded in our preliminary experiments the discoloration of the glass tubes was not corrected for nor eliminated. The phenomenon of discoloration of the glass tubes is probably a close kin to that going on in the luminous material itself. This semblance is strikingly seen in the case of radium bromide, which becomes very much discolored while decaying. There is another instance of this discoloration in the paleochroic halos. In the latter case it has been found by Jolly that the hypothesis of ionization is very tenable—the state of ionization persisting for ages in the highly insulating mica. This suggests ionization at the base of the two former cases. In all these cases discoloration disappears upon heating—

[3] Paterson, Walsh, and Higgins: *Proc. Phys. Soc. of L.*, June 15, 1917, p. 215.

in the first two accompanied with a flash of light. It is probable, also, that the paleochroic halos too would give out in the form of visible radiation some of the energy stored in them ages ago, that could be seen if a sufficient number of the halos were heated in a dark room. The discoloration in glass tubes varies with the kind of glass. Some become dark brown, others purple, others dirty gray.

We have recorded some spectro-photometric data relating to the tube containing the radium bromide No. 1 in Fig. 13. The data were obtained by means of a spectropyrometer. The tube was cemented across the slit. The ordinary calibration of the

FIG. 13.



Energy distribution. Emissivity vs. wave-length.

instrument cannot be used, and the ordinates are to be considered relative values only.

Curve *A* shows the distribution of the visible energy after the tube had been heated for one minute on the previous day; curve *B* gives the same immediately after having been heated, taken the same day as curve *A*; curve *C* shows the same after two weeks had elapsed, and then immediately after heating for two minutes on a dull red plate. It is undoubtedly the discoloration of the tube that is complicating matters here. These observations were made before we had made our final set-up for a series of tubes of known content described later, and should be repeated and extended.

The data which we are to discuss below refer to a series of samples of radium bromide—barium bromide as carefully prepared as possible. These samples were placed in small tubes and labelled Nos. 1, 2, 3, 4, and 5, in the order of their radium content—48.5, 31.2, 11.2, 3.0, and 0.51 per cent. radium element respectively. The tubes into which these materials were placed were made of "pyrex" glass; were somewhat less than two millimetres inside diameter, thin walled, and from four to five centimetres long. The tubes were made long to eliminate the effects of discoloration of the glass. When observations were made the material was shaken into one end of the tube, and shaken into the opposite end after every observation. The end at which the materials were observed discolored less than if the materials had been allowed to remain there constantly. Furthermore, this end could be slightly heated to clear the glass whenever desired without affecting the material.

This method was very satisfactory in all cases where the material was homogeneous in structure. In the case of the tube No. 3 of the last series, the shaking from end to end caused irregularities in the brightness to appear, because there was present a small core of the material, formed by fusion possibly, comparable in diameter with the diameter of the tube.

The photometric set-up for these observations is that in Fig. 1. A tungsten point-source lamp (110-volt, 100-watt) which had been calibrated for all voltages within the necessary range, is the standard. The range of brightness in this series of tubes was extensive, necessitating using different lamps or the lamps at different voltages or a series of screens. In our procedure we combined the last two methods on a photometer bar, three metres long.

There was usually present a color difference, to eliminate which would have called for a series of color screens or a variable-tint-screen. We used one and the same screen to give an approximate color-match for all samples for all times. This consisted of a disc of "daylight" glass for tungsten lamps, together with another plate of cobalt glass. The first was about 5 mm. thick and the second 3 mm. thick. These pieces were cemented together. This we called screen No. 2. The screen used to reduce the intensity when the range of the bar had been reached was a ground-glass screen labelled No. 4. The transmission of screen No. 4 was obtained at several intensities of illumination and with

the lamp at several different voltages. The variations were not large and well within our experimental errors. The transmission is 13 per cent. To obtain the last observations recorded in Fig. 15 a second ground-glass screen was used, whose transmission is 21.6 per cent.

The transmission of screen No. 2 was more difficult to obtain. It varied with the voltage of the lamp and with the intensity of illumination for every voltage. The difficulties of comparing the intensities of colored light at relatively low intensities are well known, but no satisfactory method has been found to eliminate them. The Purkinje phenomenon is very strong, and in extreme cases the inverse square law cannot be relied upon for calculating the intensity. We have determined the transmission of screen No. 2 by two methods: first, by making a photometric balance with and without the screen, with all conditions precisely the same as when observations were made for record of the luminous materials when the screen was used; secondly, by the use of an illuminometer, when the relative position of the screen remained the same, but the method of observation was altered. The two series of values differed less from each other than the separate values obtained by either method when the intensity was varied. The intensity to which the transmission is referable is 71 millilamberts. This is an intensity which we could get upon the bar with the lamp at any voltage within the range used. With the lamp voltage at 80, 85, 90, and 95 the transmission is 0.064; with the lamp voltage at 100, 110, 115, and 120 the transmission is 0.071. These values were assumed constant for all intensities.

The reflection factor of the celluloid disc coated with magnesium oxide was determined by means of an illuminometer, as previously described, and is 70.9 per cent.

The series of tubes were prepared on October 23 from the same solution concentrated by successive crystallizations; were then dried and placed in small sealed tubes, where they were kept for a few days before their γ-ray activity was measured and the percentage of radium element calculated. The material was then placed in the small tubes for observation.

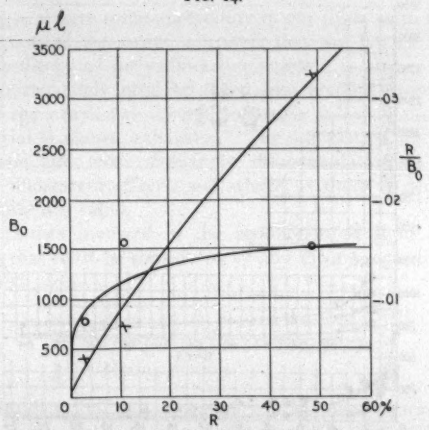
By means of the furnace shown in Fig. 11 we found that it was necessary to heat these preparations to a temperature of 480° C. to get maximum brightness.

On October 24, 3.20 P.M., all five samples were exposed to the

atmosphere by breaking the ends off the tubes and inserted into the furnace. For a receptacle in this case a large brass cylinder was used, having small holes for receiving the tubes and having a larger hole in the opposite end to receive the thermocouple. By this means we were assured that all the tubes would be subjected to the same temperature, which was 520° C.

Observations were made of the brightness of each tube, and are as follows: No. 1, 3012 μl; No. 2, 610.1; No. 3, 469; No. 4, 283; No. 5, 130. Our observations were interrupted until November 19, 4.21 P.M. Then we transferred all the samples into new

FIG. 14.



Effect of varying percentages of radium on initial brightness.

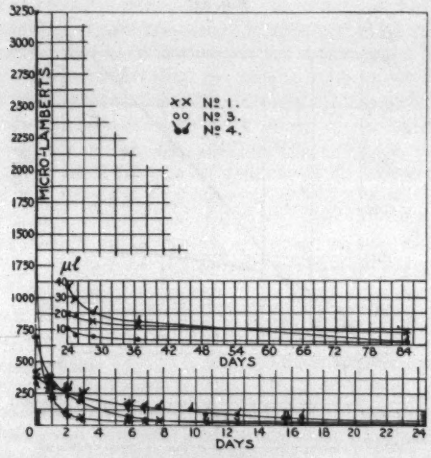
tubes, except No. 1, and obtained a new sample of No. 2 from the original stock. The transfer was made on account of the fact that the size and shape of the tubes were not satisfactory. No. 2 now had become almost non-luminous. We had reason to suspect No. 2 had become contaminated in manipulating it. After heating in the furnace to a temperature of 480° C., the brightness of tubes 1, 3, 4, and 5 was 3100, 764, 590, and 146 respectively.

On November 20, 2.33 P.M., tubes Nos. 1, 3, and 4 were opened, placed in the furnace, and heated to 520° C. From this time on we made continuous observations on these three tubes, as

shown in Fig. 15. No. 5 was accidentally contaminated with oxide from the furnace.

One of the striking features about these curves is that they cross and recross. This is in contrast to similar curves recorded for the zinc sulphide paints. Another feature is the fact that the relationship between initial brightness and percentage of radium element is not linear, but reaches a saturation value. This is shown in Fig. 14. The type of curve which seems, from our data, to be required, is given by $B_o = AR^c$. Where B_o = initial bright-

FIG. 15.



Final data. Brightness *vs.* time.

ness; R = per cent. radium; A and c are constants; $A = 141.8$, $c = 0.8$.

The curve for No. 4 is less definite than those for Nos. 1 and 3. This scattering of the observations is due to the rather compact core, which presented a different aspect whenever the tube was shaken. Curve for No. 1 falls below both the lower curves within the first 24 hours, and the curve for No. 3 falls below that for No. 4 within 48 hours. After 9.5 days, however, the curve for No. 3 has fallen below that for No. 1 and continues so; while the

curve for No. 4 falls below that for No. 1 for 10 weeks, and will eventually also fall below the curve for No. 3. Thus, after an interval of several months, the brightness of these materials will again arrange themselves in the order of the radium content.

Although the crossing of the curves is in general agreement with Rutherford's theory, nevertheless a simple exponential curve is not adequate, through the extent of time shown, to represent the data. On the other hand, the equations of Walsh [4] become very cumbersome to test accurately with the data here. It appears, however, that they cannot be satisfactory on account of the intersections.

There is always some uncertainty in our tubes as to the exact concentration of the α-rays whenever they are heated.

In the theory of the radio-active paints it is always assumed that the α-rays only need be taken into account; whereas the effects of the γ-rays may become noticeable at low intensity when the material is almost exhausted. The stimulation by γ-rays is less drastic and more similar to the stimulation to produce ordinary fluorescent effects, and where, if there is decay, it is considerably less rapid.

The factors involved in the production of light by these materials that must be considered by any theory regarding it are as follows:

1. A destruction.
2. A change in optical properties.
3. A reconstruction.

The fundamental fact that the brightness decays more rapidly than the decay of the radio-active material is evidence of some sort of destruction. During this period of decay the color of the material changes. It becomes optically more opaque to the visible radiation, just as a photographic plate will darken when exposed to α-rays, β-rays, or γ-rays. This darkening is sometimes very marked. Due to this opacity, the visible radiation produced below the surface of the material is more and more absorbed as time goes on, and therefore can add less and less to the surface brightness. Changes in color have been observed in barium platinocyanide when stimulated by rays from radium. To take proper

[4] *Proc. R. S.*, **93A**, October, 1917, p. 550.

reckoning of this element a knowledge of the laws of blackening by radio-active radiations—*e.g.*, of glass, mica, or photographic plates—is essential.

Some form of reconstruction seems necessary to account for the ever-decreasing rate of decay as the material becomes older. This reconstruction may be one of several kinds. It may be a re-forming of the " active centres " postulated by Rutherford and which is taken account of as a recombination factor in recent work;[5] or it may be that of the more simple and definite concept of recombination of ions; or it may be of the same nature as the reconstruction going on in the ordinary fluorescent materials excited by radiation of some definite wave-lengths, where there is no disruption of molecules or groups of molecules, or where there may not even be any formation or recombination of ions; in case of the luminous materials under consideration it would have to be assumed that the stimulus is the γ-rays or other secondary radiations.

The data presented in Fig. 12 clearly show that for any temperature there is a definite equilibrium state; so that, if a certain configuration of molecules is essential in order to produce light with α-rays, these results would indicate that there is some constant which would be indicative of the number of such configurations at any temperature, and that the assumption would be logically made that these configurations are breaking up and reforming at ordinary temperatures. It should be pointed out that this same condition of affairs would be consistent with an ionization hypothesis. A study of the electrical resistance of the substance before and after heating and while decaying may throw light upon this point.

The curve of Fig. 12 shows unmistakably that the luminescence is an accompaniment of a molecular state brought about by heating, whatever be the immediate mechanism of the light-production. The humps in this curve indicate, also, that there are several phases of the substance.

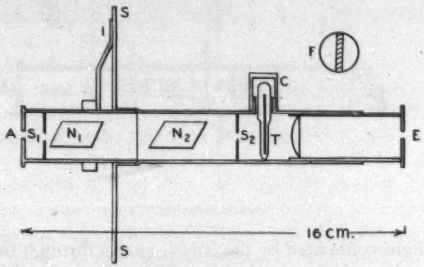
It is obvious that if the initial brightness or any given percentage of the initial brightness that is possible with any one sample of material could be readily reproduced the luminescent material is theoretically adaptable to be used as a standard light-

[5] Walsh, *loc. cit.*

source in photometry and pyrometry and in other instances where portability and compactness are most desirable. It is more radical to suggest, in the present state of knowledge, that in these self-luminous compounds there may be an absolute standard of brightness for illuminating engineering! In the cases which we have observed there is reason to believe that the luminous material may have a life equal to the life of the radio-active substance used. In the case of radium the half-life is 1730 years. The nature of the decay in radium is very well known, so that the decrease in brightness due to the decay of the stimulus could be calculated for any time during this period.

We have constructed such instruments, using these materials

FIG. 16.



Optical instrument.

along the lines shown in Figs. 16 and 17. In both of these designs we have used Nicol prisms merely as a convenient method to vary the intensity of the light.

The symbols refer to both figures: N_1, N_2, Nicol prisms; S_1, S_2, diaphragms; I, index; S, graduated disc; T, tube containing luminous material; c, covering to exclude extraneous light; A, aperture through which the rays of light from the surface looked at enter; E, eye-piece; F, photometric field (shaded portion is illuminated by the tube T).

In Fig. 16 the tube T containing the luminous material is a hard-glass capillary tube whose opposite sides for a distance of about 1 cm. are ground plane and polished.

The tube is viewed directly and less radio-active material is

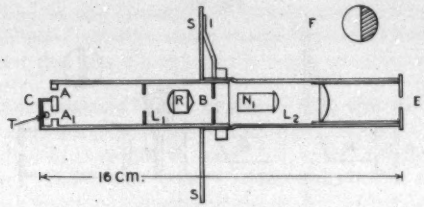
required. The brightness of the tube T must be the brightness of the least bright surface that is to be looked at, or less.

In securing a photometric balance the light from the source looked at is reduced by rotating the Nicol prism N_1. The amount by which the intensity was reduced is read on the scale S.

The brightness of the tube T can at any time be brought back to its original value by removing and heating.

In Fig. 17 the light from the tube T undergoes the same losses as the light from the source. There is no limit to the brightness of the tube T, but it requires more radium to make it appear of any definite brightness in the field of view than in the previous set-up.

FIG 17.



Optical instrument.

The light collimated by the lens L passes through the Rochon prism R, where the two oppositely polarized pencils of light from A and A_1 are produced. These pencils are brought together by the bi-prism B; through the Nicol N_1 and lens L_2.

We hope, in a future communication, to present further data showing in more detail the behavior of these materials and bearing both upon the theory and the use of them.

We wish to express our thanks and appreciation to the parties mentioned in the text, both for materials and encouragement, and particularly to the Cummings Chemical Company, of Lansdowne, Pa., who furnished all of the various salts used in these experiments.

PHYSICS OF THE AIR.*

BY

W. J. HUMPHREYS,

Professor of Meteorological Physics, United States Weather Bureau.

CHAPTER XIV (*Continued*).

Crushing Effects.—One of the more surprising phenomena of the lightning discharge is the crushing of hollow conductors, an effect that gives some idea of the strength of current and quantity of electricity involved, and therefore deserves a full discussion.

Pollock and Barraclough[117] have described and explained this phenomenon in connection with a hollow copper cylinder: outside diameter 18 mm., inside 16 mm., lap join 4 mm. wide, 2 mm. thick. In what follows, however, reference will be had to a remarkable and even more instructive product of the same phenomenon kindly lent by Mr. West Dodd, of Des Moines, Iowa. Fig. 114 shows two originally duplicate (so reported), hollow, copper lightning rods, one uninjured (never in use), the other crushed by a discharge. The uninjured rod consists of two parts, shown assembled in Fig. 114, and separate in Fig. 115. The conical cap, nickel plated to avoid corrosion, telescopes snugly over the top of the cylindrical section, and when in place, where it is left loose or unsoldered, becomes the ordinary discharge point.

The dimensions are:

Section	Outside Diameter	Inside Diameter
Cylinder	16.0 mm.	14.65 mm.
Cone shank	17.4 mm.	16.0 mm.

Length of conical cap, cylindrical portion, 7 cm., total 19 cm.

Both the cylindrical and the conical portions of the rod are securely brazed along square joints.

The general effects of the discharge, most of which are obvious from the illustrations, were:

1. One or two centimeters of the point were melted off.
2. The conical portion of the top piece and all the cylindrical

[117] *Jr. and Proc. Roy. Soc. N. S. Wales*, 39, p. 131, 1905.

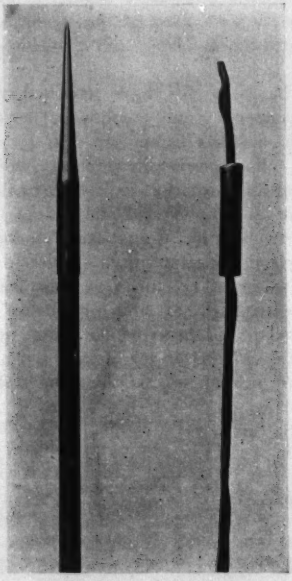
* Continued from page 232, vol. 186, August, 1918.

rod except the upper 2 centimeters, roughly, within the cap, were opened along the brazed joint.

3. The brazing solder appears to have been fused and nearly all volatilized—only patches of it remain here and there along the edges.

4. The upper end of the cylindrical rod was fused to the cap just below its conical portion.

FIG. 114.



Originally duplicate hollow copper lightning rods; one never used, the other crushed by a lightning discharge.

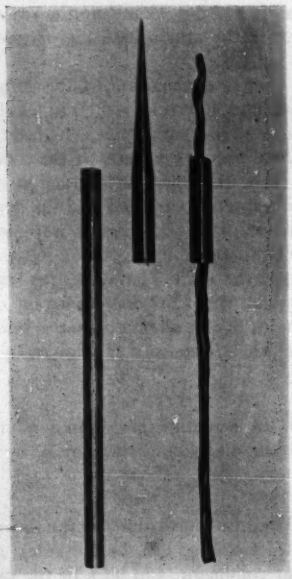
5. The rod was fused off where it passed through a staple. Whether a bend in the conductor occurred at the place of fusion is not stated.

6. The collapse of the cylindrical rod extended up about 5 centimeters into the cap.

7. The cylindrical portion of the cap, about 7 centimeters in length, was uninjured, even the brazing was left in place.

What force or forces caused this collapse? Possibly it might occur to many that it was produced by the reaction pressure from an explosion-like wave in the atmosphere due to sudden and intense heating. But however plausible this assumption may

FIG. 115.



Same as Fig. 114, except unused rod is not assembled.

seem at first there, nevertheless, are serious objections to it, some of which are:

(*a*) While explosions with their consequent pressures may be obtained by passing a powerful current along a conductor they seem to occur only with the sudden volatilization of the conductor itself, which in this case did not take place.

(*b*) The heating of the enclosed air should have produced a pressure from within more or less nearly equal to the pressure simultaneously caused from without, and thereby have either prevented or at least greatly reduced the collapse.

(*c*) The assumption that the crushing of the conductor was due to mass inertia of the suddenly heated air offers no solution whatever of the collapse of the rod up into the shank of the cap.

For these reasons it seems that the idea that the collapse of the conductor may have been caused by the reaction pressure of an explosion wave in the atmosphere due to sudden heating, is untenable.

Probably the correct explanation of the collapse, as already offered by Pollock and Barraclough,[118] an explanation that at least must involve an important factor, is as follows:

Each longitudinal fiber, as it were, of the conductor attracted every other such fiber through the interaction of the magnetic fields due to their respective currents, and the resulting magnetic squeeze on the hollow rod, whose walls were weakened by the heating of the current, caused it to collapse in the manner shown.

As is well known the force, f, in dynes per centimeter length, with which a straight wire carrying a current of I amperes is urged at right angles to the direction of the lines of force of a uniform magnetic field of intensity H is given by the equation

$$f = \frac{IH}{10}$$

Also, the value of H, r centimeters from a relatively very long straight conductor carrying I amperes, is given by the relation

$$H = \frac{2I}{10r}$$

Now, as developed by Northrup[119] in the theory of his heavy-current ammeters, let a, Fig. 116, be the outer, and b the inner radius of a tubular conductor, and let r be the radius of any intermediate tube of infinitesimal thickness, dr. Also let the conductor as a whole carry a uniformly distributed current of I amperes. Then the value of the magnetic force, at the end of the radius r, is given by the equation

$$H_r = \frac{2\,I\,(r^2 - b^2)}{10\,r\,(a^2 - b^2)}$$

[118] *Loc. cit.*

[119] *Trans. Amer. Electrochem. Soc.* 15, p. 303, 1909.

which depends upon the fact that only those portions of the current less than r distant from the axis are effective—the forces due to the outer portions neutralizing each other. Also the strength of the current, dI, carried by the cylinder of radius r and infinitesimal thickness, dr, is given by the relation

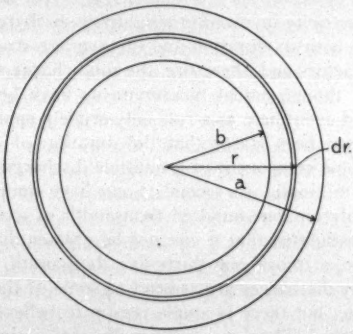
$$d\,I = \frac{2\,I\,r\,dr}{(a^2-b^2)}.$$

Hence, under the assumed conditions, the normal pressure, dP, per unit area on the cylinder of radius r and thickness, dr, may be determined by the equation

$$dP = \frac{2\,I\,r\,dr}{2\,\pi\,r\,10\,(a^2-b^2)} \times \frac{2\,I\,(r^2-b^2)}{10\,r\,(a^2-b^2)}$$

Hence the total normal pressure, P, per square centimeter of the *inner* surface is given by integrating the above expression be-

FIG. 116.



Section of a hollow tubular conductor, inner radius, a, outer radius, b.

tween the limits b and a. That is,

$$P = \frac{2\,I^2}{100\,\pi\,(a^2-b^2)^2}\left(\int_b^a r\,dr - b^2\int_b^a \frac{dr}{r}\right)$$

$$= \frac{2\,I^2}{100\,\pi\,(a^2-b^2)^2}\left[\tfrac{1}{2}\,(a^2-b^2) + b^2\log_e\frac{b}{a}\right]$$

$$= \frac{I^2}{100\,\pi\,(a^2-b^2)}\left(1+\frac{2\,b^2}{a^2-b^2}\log_e\frac{b}{a}\right)$$

Substituting for a and b their numerical values, 0.8 cm. and 0.7325 cm. respectively, it is found that

$$P = \frac{I^2}{379.1}$$

If we assume P, the pressure in dynes per square centimeter of the inner surface, to be 10^6, approximately one atmosphere, then

$$I = 19{,}470 \text{ amperes, approximately.}$$

If the lightning discharge were alternating the current density would be greatest in the outer portions of the conductor, and therefore the total current would have to be still heavier than the above computed value to produce the assumed pressure. However, from reasons already given, it seems extremely probable that the discharge is unidirectional and not alternating, and therefore that the computed strength of current, though of minimum value, is substantially correct.

Quantity of Electricity in Discharge.—To determine the amount of electricity involved in a lightning discharge it is necessary to know both its duration and the average strength of current. Both factors and, therefore, the total charge are known to vary greatly, though actual measurements have been comparatively few and even these as a rule only crudely approximate.

It has often been stated that the duration of a single discharge, or single component of a multiple discharge, is not more than one one-millionth of a second. Some have computed a duration of roughly one one-hundred thousandth of a second, while others have estimated that it can not be greater than one forty thousandth or, at most, one thirty-five thousandth of a second. Possibly many discharges are as brief as some of these estimates would indicate, but there is ample reason to believe that others are much longer. Thus one occasionally sees a streak of lightning that lasts fully half a second without apparent flicker, while more or less continuous or ribbon discharges are often photographed by moving cameras. But in addition to these evidences we have also a number of time-measurements made by Rood[120] with a rotating disk, ranging from less than 1/1600 second up to 1/20 second, and others, 38 in all, by DeBlois[121] with an oscillograph, ranging from 0.0002 second to 0.0016 second. In one

[120] *Amer. Jr. Sci.*, vol. 5, p. 163, 1873.

[121] *Proceedings Am. Inst. Elec. Eng.*, vol. 33, p. 568, 1914.

case De Blois found the durations of 5 sequent discharges to be 0.0005, 0.0015, 0.0016, 0.0014 and 0.0012 second respectively, or 0.0062 second as the summation time of these principal components of the total discharge. Hence it seems probable that the actual time of a complete discharge, that is, the sum of the times of the several components, may occasionally amount to at least 0.01 second.

The second factor mentioned above, the strength of discharge, is even more difficult to determine, and but few estimates of it have been made.

Pockels,[122] adopting the ingenious method of measuring the residual magnetism in basalt near a place struck by lightning and comparing these quantities with those similarly obtained in the laboratory, concluded that the maximum strength of current in such discharges amounted occasionally to at least 10,000 amperes. However, the loss of magnetism before the measurements were made, and other unavoidable sources of error, indicate that the actual current strength probably was much greater than the estimated value—that the maximum strength of a heavy lightning discharge certainly amounts to many thousands of amperes, occasionally perhaps to even one hundred thousand.

Since the above estimates are very rough it would be well to check them, even though the check itself be equally crude. Hence it may be worth while further to consider the crushed lightning rod with this particular object in view.

From the dimensions already given of this rod, outside diameter 1.6 centimeters, inside diameter 1.465 centimeters, it follows that its cross sectional area is about .325 square centimeter, and its weight, therefore, approximately 2.9 grams per centimeter length. Further, from the fact that the brazed joint was opened and most of the solder removed, apparently volatilized, and the further fact that the rod itself, in several places, indicates incipient fusion, it would seem that the final temperature may have been roughly 1050° C. If so the rod must have been heated about 1025° C., since its temperature just before being struck probably was approximately 25° C. But the average specific heat of copper over this temperature range is roughly 0.11 and therefore the calories generated per centimeter length about 327.

[122] *Annalen d. Phys.*, **63**, p. 195, 1897; **65**, p. 458, 1898; *Met. Zeit.*, **15**, p. 41, 1898; *Phys. Zeit.*, **2**, p. 306, 1901.

Now one ampere against one ohm generates 0.24 calories per second. Hence, since the resistance of the uninjured or check rod, as kindly measured by the Bureau of Standards, is practically that of pure copper, the average resistance of the crushed conductor over the assumed temperature range probably was about 17 microhms per centimeter length,[123] we have the equation

$$\frac{24}{10^2} I^2 \frac{17}{10^6} t = 327,$$

in which I is the average strength of current, and t the actual time of discharge. Assuming that $t = .01$ sec. we get, roughly,

$$I = 90{,}000 \text{ amperes.}$$

A current of this average value would indicate a maximum value of perhaps 100,000 amperes.

It was computed above that a current of 19,470 amperes in the given hollow conductor would produce on it a radial pressure of 10^6 dynes per square centimeter, or about one atmosphere. Hence 100,000 amperes would give a pressure of 2638×10^4 dynes per square centimeter, or approximately 400 pounds per square inch; enough, presumably, to produce the crushing that actually occurred.

A current of 90,000 amperes for .01 second would mean 900 coulombs or 27×10^{11} electrostatic units of electricity; certainly an enormous charge in comparison with laboratory quantities, but after all a surprisingly small amount of electricity, since it would electrolyze only .084 of a gram of water. It must be distinctly remembered, however, that these estimates are exceedingly rough, and further that this particular discharge presumably was exceptionally heavy since it produced an exceptional effect.

An interesting method of measuring the resultant electric exchange between earth and cloud incident to a lightning discharge recently has been used by C. T. R. Wilson.[124] Values up to about 50 coulombs were found, but it is not stated whether the discharges were single or mutliple, nor are their durations given.

From the above various observations and experiments, therefore, it appears that in some cases the strength of current in a lightning discharge probably amounts to many thousands of am-

[123] Northrup, JOURNAL FRANKLIN INSTITUTE, 1914, 177, p. 15.
[124] *Proc. Roy. Soc. A.*, 92, p. 555, 1916.

peres, and that the total duration of the individual or partial discharges may be several thousandths of a second.

Danger.—It is impossible to say much of value about danger from lightning. Generally, it is safer to be indoors than out during a thunderstorm, and greatly so if the house has a well-grounded metallic roof or properly installed system of lightning rods. If outdoors it is far better to be in a valley than on the ridge of a hill, and it is always dangerous to take shelter under an isolated tree—the taller the tree, other things being equal, the greater the danger. An exceptionally tall tree is dangerous even in a forest. Some varieties of trees appear to be more frequently struck, in proportion to their numbers and exposure, than others, but no tree is immune. In general, however, the trees most likely to be struck are those that have either an extensive root system, like the locust, or deep tap roots, like the pine, and this for the very obvious reason that they are the best grounded and therefore offer, on the whole, the least electrical resistance.

If one has to be outdoors and exposed to a violent thunderstorm, it is advisable, so far as danger from the lightning is concerned, to get soaking wet, because wet clothes are much better conductors, and dry ones poorer, than the human body. In extreme cases it might even be advisable to lie flat on the wet ground. In case of severe shock, resuscitation should be attempted through persistent (hour or more, if necessary) artificial respiration and prevention from chill.

As just implied, the contour of the land is an important factor in determining the relative danger from lightning because, obviously, the chance of a discharge between cloud and earth, the only kind that is dangerous, varies somewhat inversely as the distance between them. Hence thunderstorms are more dangerous in mountainous regions, at least in the higher portions, than over a level country. For this same reason, also (inverse relation between distance from cloud to earth and frequency of discharge between them), there exists on high peaks a level or belt of maximum danger, the level, approximately, of the base of the average cumulus cloud. The tops of the highest peaks are seldom struck, simply because the storm generally forms and runs its course at a lower level.

Clearly, too, for any given section the lower the cloud the greater the danger. Hence a high degree of humidity is favor-

able to a dangerous storm, partly because the clouds will form at a low level and partly because the precipitation, and probably therefore the electricity generated will be abundant. Hence, too, a winter thunderstorm, because of its generally lower clouds, is likely to be more dangerous than an equally heavy summer one. Finally, as already explained, cyclonic or other cross-current thunderstorms presumably are more dangerous, than those due to local heating, and therefore the thunderstorm of middle latitudes generally more dangerous than one of equal severity in the tropics.

It may also be interesting to note that the front edge of a thunderstorm probably is more dangerous than any other portion; more dangerous because it is immediately beneath the region of most active electrical generation, and because objects here often still are dry and therefore if struck more likely to be penetrated and fired than later when wet and thus partially shielded by conducting surfaces.

Protection.—If, as seems quite certain, the lightning discharge follows, or tends closely to follow, the instantaneous lines of electric force then it is obvious that whatever changes the direction of this force must correspondingly alter the path the flash shall take. To the extent then that the direction of electric force near the surface of the earth can be changed, but in general to only this extent, lightning protection is possible. If also the strength of the field could materially be reduced clearly the discharges might be rendered less violent and even less frequent, but, as will be explained presently, there is no evidence that the strength of the field can greatly be altered by any practicable means. Hence it appears that protection from lightning must be sought through directional control, which is both possible and practical,[125] rather than through prevention.

Assume, in accordance with observation, that over an extended horizontal surface, a prairie for instance, the lines of electric force are vertical; determine how the field of force will be modified by the presence of a given structure. Obviously if the structure itself consists of such non-conducting materials as

[125] O. S. Peters, "Protection of Life and Property Against Lightning." Technologic Paper, 56, Bureau of Standards, Washington, D. C., 1915. Also R. N. Covert, "Modern Methods of Protection Against Lightning," *Farmers' Bulletin 842*, Department of Agriculture, Washington, D. C., 1917.

wood and stone there will be but little directional change of the electric force. If, however, it is made of a conducting substance the direction of the force will be changed, but to an extent and over an area that depend upon the size and shape of the structure in question. In general this effect is not calculable, but fortunately it may be definitely computed in the special case of a conducting semi-ellipsoid with vertical axis and standing, as would a right one, on the conducting surface—the actual surface if wet, somewhat below if dry. The ground and all parts of the conductor, unless actively discharging, will have the same potential. Hence by varying the values of the three diameters of the semi-eclipsoid a fair approximation may be made to many ordinary structures and their effects on the electric field estimated, in some cases roughly, in others with even a high degree of accuracy. Thus, by making each of the horizontal diameters small and the vertical one relatively very large, the modification of the field by a single upright metallic rod may be computed very closely, and its efficiency as a protection against lightning approximately determined. This has recently been done by Sir J. Larmor and Mr. J. S. B. Larmor,[126] who say that

"In fact, if the undisturbed vertical atmospheric field is F, the modified potential

$$V = -F_z + A_z \int_\epsilon^\infty \frac{d\lambda}{(a^2+\lambda)^{\frac{1}{2}}(b^2+\lambda)^{\frac{1}{2}}(c^2+\lambda)^{\frac{3}{2}}}$$

will be null over the ground, and also null over the elllipsoid (a, b, c), provided

$$\frac{F}{A} = \int_0^\infty \frac{d\lambda}{(a^2+\lambda)^{\frac{1}{2}}(b^2+\lambda)^{\frac{1}{2}}(c^2+\lambda)^{\frac{3}{2}}}$$

"For our special case of a thin symmetrical semi-ellipsoid of height c, this gives

$$V = -F_z + A_z \int_\epsilon^\infty \frac{d\lambda}{\lambda\,(c^2+\lambda)^{\frac{3}{2}}}$$

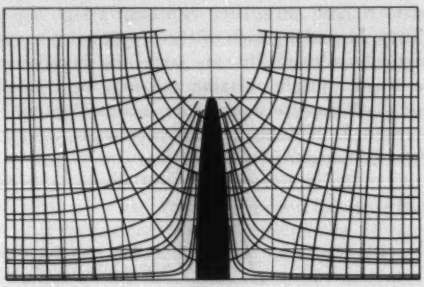
"The value of this integral, however, increases indefinitely towards its lower limit as ϵ falls to zero, when a and b are null. Thus as the semi-ellipsoid becomes thinner the value of A dimin-

[126] *Proceedings Roy. Soc. London*, A 90, p. 314, 1914.

ishes without limit; that is, the modification of the field of force by a very thin rod is negligible along its sides unless close to it. A thin isolated rod thus draws the discharge hardly at all unless in the region around its summit."

This is not to be taken as a condemnation of lightning rods in general. It only shows that a single vertical rod affords but little protection to things in its neighborhood. When, however, the horizontal diameters of the semi-ellipsoid are of appreciable length the directions of the otherwise vertical lines of force are greatly changed for some distance on all sides, as illustrated by Fig. 117, adapted from the paper quoted above. Hence one

FIG. 117.



Vertical field of electric force disturbed by a conducting, semi-ellipsoidal column.

method, and so far as known the only method, of at least partially protecting an object from lightning consists in surrounding it by a hollow conductor, or by a well-grounded conducting cage. Perfect protection ordinarily is not practical, if even possible.

By this method the lightning that otherwise would hit at random is guided to the conducting system and through it, if all goes well, harmlessly to the ground. It must be clearly remembered, however, that this discharge, though in all probability unidirectional, is extremely abrupt and of great amperage and therefore possesses the dangerous voltage and inductive properties of alternating currents of high frequency and large volume. It should also be remembered that although the successive partial discharges that make up the usual lightning flash follow

the same ionized path, this path itself, shifted by the winds, probably often guides one or more of the secondary or sequent discharges to an entirely different object from that hit by the first.

From these fundamental principles it is easy to formulate general rules (details may be varied indefinitely) for the construction of an efficient system of lightning protection.

CONDUCTORS.

Since lightning discharges occasionally involve very heavy currents, it is necessary that the conductors of the protective system be sufficiently large to prevent fusion. Probably copper is the best material to use, mainly because non-corrosive, or practically so, in the atmosphere and therefore very durable, though aluminum and galvanized iron are also good. If copper, a weight of 370 grams per meter (4 ounces per foot) might suffice, but a greater weight possibly would be better. The shape of the cross section appears to be of comparatively small importance.

TERMINALS.

Because of the distortion of the electric field due to the object to be protected, house for instance, and to the system of conductors, each ridge, peak, chimney and other highest point should be capped or surmounted by a conductor that is well grounded.

It would be better if the conductor extended 2 meters or so above each of these salients, though the protection is still fair to good with much shorter projections, or even none at all. Whether or not each projection in turn is provided with the customary sharp points probably is of small importance—rather a matter of taste or sentiment than a necessity. To be sure, it often is asserted that sharp points discharge so freely that they thereby largely *prevent* lightning. But this assumption has little support from observation or experiment. Lodge,[127] for instance, says: "*I find that points do not discharge much till they begin to fizz and audibly spit; and when the tension is high enough for this, blunt and rough terminals are nearly as efficient as the finest needle points.* The latter, indeed, begin to act at comparatively low potentials, but the amount of electricity they can get rid of at such potentials is surprisingly trivial, and of no moment whatever when dealing with a thundercloud."

[127] "Lightning Conductors and Lightning Guards," London, 1892, p. 370.

SYSTEM.

Because a single rod modifies the electric field only in its near neighborhood, and because the wind shifts the ionized or conducting path during the interval between successive partial discharges, it is obvious that the smaller the spaces left bare by the conductive covering the more effective the protection. A steel frame building with the framing well grounded from its lower portions and connected at all upper corners, and other places of near approach, to a metallic roof from which in turn conductors extended above the chimney tops and other protrusions, would, therefore, appear to be especially well protected from lightning damage.

A stone or wooden building should have electrically continuous rods up each corner to the eave, thence to and along the ridge, with such side branches and elevated projections as the size and shape of the building, and other considerations, may require. In general, no place on the roof should be more than 3 meters (10 feet) from some portion of the protective system. Further, the principal and secondary conductors must be so placed that from any point the ground may be reached by a continuous *downward* course.

Protection would also be increased by surmounting each corner with a conducting rod 3 to 4 meters tall, properly connected to the rest of the system. Architectural considerations, however, might often forbid this additional precaution.

JOINTS.

To facilitate the discharge as far as possible the conductors should be as nearly as practicable continuous. Hence all necessary joints should be electrically good and mechanically secure. Well-made screw joints turned up tight appear to be the best.

BENDS.

Since electric surges tend to arc across sharp angles lightning rods must have no short bends. Changes in direction must be avoided as far as possible and wherever necessary be made gradually along a curve of 30 centimetres (one foot) radius, or more,—self induction must be kept at a minimum.

ATTACHMENT.

The rods should be attached to the building with holders of the same material as the rod itself. This prevents corrosion, and also secures electrical connection to the roof and sides which usually are wet and conducting during a thunderstorm.

GROUND CONNECTIONS.

Because of the considerable resistance of even very damp earth, ground connections should be as good and as many as practicable. Every descending rod, and there would better be one at each corner, and on large buildings even more, should be sunk straight down to perpetually damp earth, if convenient connected also to underground water pipes, and of course protected from injury a couple of meters above ground. Generally copper is best for this purpose. If iron is used it should not be packed in coke or charcoal, since either would cause the iron more rapidly to corrode.

CONNECTION TO NEIGHBORING CONDUCTORS.

The high potential and strong induction of the lightning discharge require that not only gutters, waterspouts, and the like, on the outside, but also all internal conductors of large size or considerable length be connected with the outer system at their upper ends and wherever they come within even two or three meters of it, cross connected with each other at points of close approach, and, finally, well grounded, from their lower ends, either directly or by proper attachment to the main conductors.

It is often stated that leaky gas pipes should be excepted from such connections. Possibly so, but in the first place gas pipes should not be allowed to leak.

SPECIAL DANGERS.

Overland wires, telephone, telegraph, light and power, necessarily are sources of danger unless provided with proper lightning arresters. However, appropriate devices of this nature commonly are installed, and therefore danger from electric wires usually is negligible. Nevertheless, it must be remembered that this distinctly is a case where the price of protection is proper forethought and adequate precaution.

A much greater source of danger, because seldom if ever

provided with an efficient lightning arrester, is the harmless-looking wire clothes line running from some part of the house to a convenient tree. The obvious remedy in this important case is either to use a cotton or other fiber rope, or else to avoid connection with the house altogether.

Still another common source of danger, especially to stock, is the ordinary wire fence. But here, too, approximate safety is easy of attainment. It is only necessary that good ground connections be made at intervals of every 100 meters (20 rods), or less—the shorter the better, so far as safety is concerned.

Finally the question of shade trees is of some importance. None is safe, but in general the danger they imply increases both with their own height and with the elevation of the ground above adjacent regions.

CHAPTER XV.

ATMOSPHERIC ELECTRICITY

THREE manifestations of atmospheric electricity, lightning (discussed in connection with the thunderstorm), the aurora polaris, and St. Elmo's fire—a "brush" discharge from elevated objects—have long been known; the first two, of course, from the beginning of human existence, and the last, as an object of the sailor's superstition, certainly since the days of ancient Greece and Rome.[128] Their identification, however, as electrical phenomena is very modern.

The following list of contributions to the science of atmospheric electricity, though fragmentary, will, perhaps, give some idea of its slow but accelerated course of development:

(*a*) The suspicion of the electrical nature of lightning by Hawksbee, who says,[129] "Sometimes I have observed the light to break from the agitated [electrified] glass in as strange a form as lightning." And also,[130] "I likewise observed that . . . it was but approaching my hand near the surface of the outer glass [a rotated open receiver containing an exhausted vessel] to produce flashes of light like lightning in the inner one"; by Wall,[131]

[128] Brand's "Antiquities," Castor and Pollux.
[129] *Phil. Trans.*, 1705.
[130] *Phil. Trans.*, 1707.
[131] *Phil. Trans.*, 1708.

. . . "by holding a finger a little distance from the [electrified] amber, a crackling is produced, with a great flash of light succeeding it . . . and it seems, in some degree, to represent thunder and lightning"; by Gray[132] . . . "this electric fire, which, by several of these experiments, seems to be of the same nature with that of thunder and lightning"; and by many others.

(*b*) The devising by Franklin,[133] in 1749, of a simple means "to determine the question, whether the clouds that contain lightning are electrified or not."

(*c*) The proof, May 10, 1752, by d'Alibard[134] (following Franklin's suggestion), that clouds in which lightning appears are electrified.

(*d*) The proof, July, 1752, by Le Monnier[135] that a tall, insulated metallic conductor becomes electrified even when the sky is absolutely clear.

(*e*) The inauguration in 1757 by Beccaria[136] of systematic and long continued (15 years) observations of atmospheric electricity.

(*f*) The invention by Thomson[137] (Lord Kelvin) of the quadrant electrometer in 1855, and the "water-dropper," about the same time, that greatly increased the delicacy and accuracy of the measurements of atmospheric electricity.

(*g*) The discovery by Linss[138] in 1887 that even the most perfectly insulated conductors lose their charges, when exposed to the air, in a manner that shows the atmsophere itself to be a conductor of electricity.

(*h*) The discovery in 1900 by C. T. R. Wilson[139] and also by H. Geitel[140] of spontaneous ionization in the atmosphere.

(*i*) The discovery in 1902 independently by Rutherford and Cook,[141] and McLennon and Burton,[142] of a penetrating radia-

[132] *Phil. Trans.*, 1735.
[133] "Experiments on Electricity," edition 1769, p. 66.
[134] Franklin, "Experiments on Electricity," edition 1769, p. 107.
[135] *Acad. Roy. des. Sciences*, 1752, p. 233.
[136] "Dell' Elettricità Terrestre Atmosgherica a Cielo Sereno," Torino, 1775.
[137] *B. A. Rept.*, 1855 (2), p. 22.
[138] *Met. Zeit.*, **4**, p. 345, 1887.
[139] *Proc. Cambr. Phil. Soc.*, **2**, p. 52, 1900.
[140] *Phys. Zeitsch.*, **2**, p. 116, 1900.
[141] *Phys. Rev.*, **16**, p. 183, 1903.
[142] *Phys. Rev.*, **16**, p. 184, 1903.

tion in the lower atmosphere, presumably from radioactive substances near the surface of the earth.

(*j*) The discovery in 1905 by Langevin[143] of slow moving or large ions in the atmosphere.

(*k*) The discovery by Simpson[144] in 1908 and 1909 that the electric charge on thunderstorm rain, and precipitation generally, is prevailingly positive.

(*l*) The discovery by Kolhörster[145] that an extremely hard or penetrating radiation exists in the atmosphere that comes from the outside—chiefly, apparently, from the sun.

ELECTRICAL FIELD OF THE EARTH.

The experiments of Franklin and others with kites and insulated vertical rods revealed a persistent difference of electric potential between the earth and the atmosphere, that soon became, and still is, the object of innumerable measurements.

Instruments.—The instruments essential for accurate measurements of the difference of potential between the earth and any point in the atmosphere are a "collector" and an electroscope. The "collector" is merely an insulated conductor provided with an adequate means of electric discharge—sharp point, flame, ionizing salt, or "dropper"—that brings it and all other conductors with which it is electrically connected to the potential in the air at the point of discharge.

The electrometer, one element of which is connected to the "collector" and thus brought to its potential while the other is grounded, or connected to a "collector" at a different level, may be any one of several types. Those generally used at present are the Thomson quadrant, Bendorf registering (adaptation of the Thomson quadrant), Wulf bifilar, and Einthoven single-fiber. The quadrant type must be kept stationary, but the others are not so restricted and give good results even on shipboard and in balloons.

Potential Gradient Near the Surface.—The vertical potential gradient near the surface of the earth varies greatly, with location, season, hour, and weather conditions—occasionally even reversing sign during storms—but the general average over level

[143] *C. R.*, 140, p. 232, 1905.
[144] *Memoirs Indian Meteorl. Dept.*, Simla, 1910, 20, pt. 8.
[145] *Deutsche Phys. Gesel.*, July 30, 1914.

areas and during fine weather appears to be of the order of 100 volts per meter, in response to a negative surface charge.

Location Effect.—Since the earth is a conductor it is obvious that the distribution on its surface and the resulting vertical potential gradient will be so modified by topography as to be smaller in narrow valleys than on the neighboring ridges. Over level regions of the same elevation the gradient appears to be largest in the interior of continents of the temperate zones and least within the tropics, and also, perhaps, in very high latitudes.

Annual Variation.—The annual variation of the vertical potential gradient near the surface of the earth differs greatly from place to place. In general it is comparatively small in tropical regions, and also anywhere on mountain tops, but large, as much in some cases as twice the annual average value, in the temperate zones where the gradient changes are roughly as follows: An increase during the fall and early winter to a maximum of perhaps 250 volts per meter, followed by a rapid decrease during spring to a moderately constant summer minimum of roughly 100 volts per meter.

Diurnal Variation.—The diurnal variation of the potential gradient, in some places fully equal to the average gradient, changes with place, season, and altitude. Its amplitude is greater along middle latitudes in the interior of continents than along low latitudes, or anywhere over the ocean; greater during winter, when it is single-crested, than summer, when double-crested. At moderate elevations, half a kilometer or less, the gradient has only a single daily maximum and minimum, whatever its surface periods.

In all cases a minimum gradient occurs about 4 o'clock in the morning. If the variation is double diurnal the second, but less pronounced minimum, occurs about mid-afternoon; the first maximum at 9 o'clock, roughly, in the forenoon, and the second at about 8 to 9 o'clock in the evening. If the variation is only diurnal, as in the winter, the maximum is attained during afternoon. Typical examples of such curves are given in Fig. 118 after Bauer and Swann.[146]

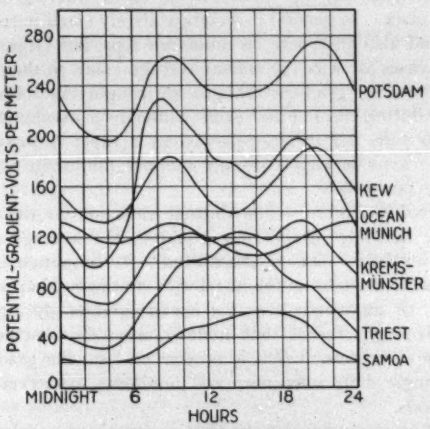
From the above facts it appears that the single daily variation of the potential gradient is fundamental, and that the sum-

[146] Publication No. 175 (Vol. III) of the Carnegie Institution of Washington.

mer afternon minimum that develops a double diurnal variation is only a shallow disturbance due, presumably, in part at least, to dust, since any material caught up from the earth obviously must carry along some of the negative surface charge and thereby decrease the gradient in the lower air.

Potential Gradient and Meteorological Elements.—Many efforts have been made to find what relations obtain between the potential gradient and the various meteorological elements, but the results in most cases are inconclusive, especially in respect to

FIG. 118.



Diurnal variation of potential gradient.

temperature, humidity, and pressure changes. Strength and direction of wind both are important through their effect on the amount of smoke, dust, factory fumes, et cetera, in the air at the place of measurement. Fog, rain, and other forms of precipitation are nearly always electrically charged and therefore often greatly modify and occasionally even reverse the potential gradient as do also heavily charged or thunderstorm clouds. Cirrus and other types of high, fair-weather clouds produce little or no effect.

Potential Gradient and Elevation.—Measurements of the po-

tential gradient from free balloons have shown that it varies greatly and irregularly through the low dust-laden stratum, and that above this layer it decreases less and less rapidly to a comparatively small value at an altitude of only a few kilometers. If the surface gradient is 100 volts per meter, it may be 25 volts per meter at an elevation of 1.5 kilometers, 10 at an elevation of 4 kilometers, 8 at 6 kilometers elevation, with similar decreases for greater heights.

Surface and Volume Charges, et cetera.—From the simple equation,

$$\frac{dN}{dn} = \frac{100 \text{ volts}}{\text{meter}} = f = 4\pi\sigma,$$

giving the electric force, f, or rate of change of potential normal to the surface, in terms of the surface charge σ per unit area, it follows that when the potential gradient at the surface of the earth is 100 volts per meter the charge is 2.65×10^{-4} negative electrostatic units per square centimeter, or 4.5×10^{5} coulombs, roughly, for the total surface charge of the earth.

Similarly, from the equation,

$$\frac{d^2V}{dn^2} = \frac{df}{dn} = 4\pi\rho$$

between the volume charge ρ and the ratio of change of the electric force to change of elevation, it appears that near the surface of the earth the net charge of the air is roughly 0.1 electrostatic unit of positive electricity per cubic meter.

ELECTRICAL CONDUCTIVITY OF THE ATMOSPHERE

It is well known that an electrified conductor exposed to the air gradually loses its charge, however carefully it may be insulated. This phenomenon was first investigated by Coulomb,[147] who found the important law that the rate of loss of charge is proportional to the existing charge, or rate of drop of potential proportional to the existing potential. In symbols,

$$\frac{dQ}{dt} = -aQ \quad \text{and} \quad \frac{dV}{dt} = -aV$$

or

$$Q_t = Q_0 e^{-at}$$

and

$$V_t = V_0 e^{-at}$$

[147] *Mém. de l'Acad. de Paris*, 1785, p. 616.

where Q_0 and V_0 are the charge and potential, respectively, at any given instant, Q_t and V_t the corresponding values t seconds, or other units of time, later, e the base of the natural logarithms, and a a constant.

The loss of charge was explained by Coulomb, and his explanation was accepted for more than a century, as due to the charging by contact of neutral molecules of air and their subsequent repulsion.

From the work begun by Linss[148] and extended by others it is now known, however, that the discharge coefficient a varies more or less from hour to hour and from season to season, and, further, that generally it is not the same for charges of opposite sign. Hence the loss of charge in addition to that which may be accounted for by imperfect insulation, is due to neutralization by numerous minute charges of the opposite sign normally present in the atmosphere—charges that render it conductive. It is also known that the values of these charges are either that of the electron or multiples thereof. Swann[149] has shown that whatever the shape of the charged body the rate of its loss of charge is given by the equation,

$$\frac{dQ}{dt} = -4\pi Q n e v$$

where Q is the charge on the object, n the number of ions per cubic centimeter of sign opposite to that of Q, v the specific velocity of these ions and e the ionic charge. In other words, the rate of supply of electricity by the ions to the charged body is $4\pi\lambda\ C\ V$, in which C is the capacity of the charged object and λ the conductivity of the air for electricity of sign opposite to that of the charge.

The conductivity, therefore, of the atmosphere may be conveniently measured by noting the rate of potential drop of a charged cylinder concentrically surrounded by a relatively large tube through which a good circulation of fresh air is maintained. Fig. 119 indicates the equipment used for this purpose on the *Carnegie* during the cruises of 1915–1916.[150] As explained in the publication referred to, if C_1 is the capacity of the whole ap-

[148] *Met. Zeit.*, **4**, 345 ,1887.

[149] *Terr. Mag. and Atmos. Elec.*, **19**, p. 81, 1914.

[150] Bauer and Swann, Publication 175 (Vol. III) of the Carnegie Institution of Washington, p. 385.

paratus, including the electroscope, and C_2 the measured capacity of the concentric cylinders, including that portion of the supporting rod A that is exposed to the air current, then

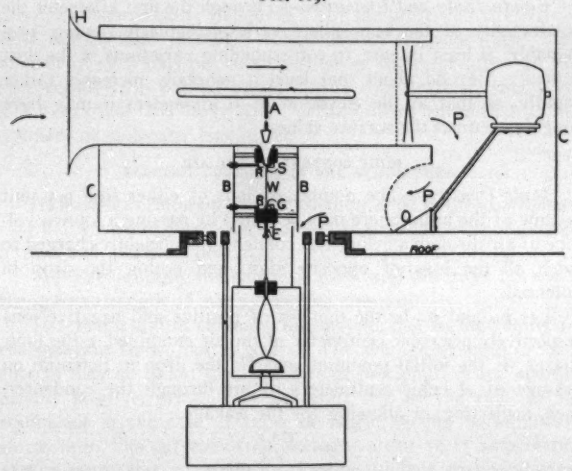
$$-C_1 \frac{dV}{dt} = 4\pi\lambda C_1 V$$

and

$$4\pi\lambda C_1 = \frac{C_1}{T} \log_e \frac{V_1}{V_2}$$

in which T is the time required for the potential to fall from V_1 to V_2. Hence both conductivities, λ_+ and λ_-, corresponding

FIG. 119.



Conductivity apparatus.

respectively to the positive and negative ions, are easily determinable.

The average value of the conductivities found during the above-mentioned cruise of the *Carnegie* were $\lambda_+ = 1.44 \times 10^{-4}$ and $\lambda_- = 1.19 \times 10^{-4}$. These are also approximately the values found over land during clear weather.

Annual Variation.—In general the conductivity is greater during the summer than during winter—the reverse of the potential gradient.

Diurnal Variation.—The diurnal variation of the conductivity is quite irregular, but is more or less the reverse of the potential gradient, that is, high in the early morning and low in the evening.

Relation to Weather.—The conductivity of the atmosphere is very small when the air is either dusty or foggy; nearly all the ions being then attached to masses so large that the velocity factor, v, in the current equation, and consequently the current itself, is quite small. On the other hand, when the air is clean and dry, the conductivity is relatively large.

Conductivity and Elevation.—Through the first kilometer the conductivity of the atmosphere varies irregularly, owing, presumably, at least in part, to corresponding variations in the dust content. Beyond about that level it generally increases rather rapidly, so that at the elevation of 6 kilometers it may have roughly 20 times the surface value.

IONIC CONTENT OF THE AIR

Ionic Density.—The number of ions of either sign per unit volume of the atmosphere may be found by passing a known volume of air through a cylindrical condenser, sufficiently charged to catch all the ions of opposite sign, and noting the drop in potential.

Let n_+ and n_- be the number of positive and negative ions respectively per cubic centimeter of the air examined, e the ionic charge, V the initial potential, and δV the drop in potential on passage of A cubic centimeters of air through the condenser, then, neglecting, or allowing for the leakage,

$$n_{\pm} = \frac{C\,\delta V}{e\,A}$$

The value of n varies greatly, being very small during foggy and dusty weather, and relatively large when the air is clear. In general it is larger during summer than winter, larger during the day time than at night, and larger when the temperature is high than when it is low. It also increases with elevation through at least the first few kilometers, but to what maximum value, and where, is not known.

Through the lower atmosphere the fair-weather values of n_+ and n_- generally are of the order of 800 and 680, respectively, per cubic centimeter.

Ionic Velocity.—The velocities v_1 and v_2, of the positive and negative ions respectively, may be computed from the corresponding values of the current, $n_+ ev$, and ionic density n_+, since the value of e is a known constant. The average value of v_+ in the lower air is of the order of $1 \frac{\text{cm/sec}}{\text{volt/cm}}$, and of $v_- 1.2 \frac{\text{cm/sec}}{\text{volt/cm}}$. Both values increase with decrease of pressure—at half the pressure the velocity is double, approximately—and therefore with increase of elevation.

Large, or Langevin Ions.—After the atmosphere is deprived of all its ions of molecular size it still is slightly conductive, because, as discovered by Langevin,[151] of the presence of relatively slow moving and therefore comparatively massive ions. The number of such ions per cubic centimeter varies greatly. In the open country this number appears to be comparatively small, but it is very great over large cities, perhaps many times that of the ordinary or molecular ions.

ELECTRIC CURRENTS IN THE ATMOSPHERE

At least four different electric currents exist in the atmosphere —two always and everywhere, or nearly so, and two sporadically in time and place. These are:

(*a*) The lightning discharge, of very brief duration, but often rising to a strength of many thousand amperes.

(*b*) Precipitation currents, or currents due to the falling of charged rain, snow, hail, et cetera. The average strength of such current may be found from the rate of precipitation and charge, usually positive, per cubic centimeter, say, of the rain, or its equivalent in the case of snow or hail. During non-thunderstorm rains this current often averages about 10^{-16} ampere per square centimeter of surface. During violent thunderstorms, however, it is far greater, even as much as 10^{-12} ampere per square centimeter for brief intervals has been reported.

(*c*) Convection currents, due to the mechanical transfer of the ions in the atmosphere from one place to another by winds, including vertical convection. The strength of such current per unit area at right angles to the direction of the wind is obtained by multiplying the wind velocity by the net density of the charge. This density may be found either by multiplying the ionic

[151] *C. R.*, 140, p. 232. 1905.

charge by the difference between the numbers of ions of opposite sign per cubic centimeter, or from the equation,

$$\rho = -\frac{1}{4\pi}\frac{d^2V}{dh^2}$$

in which ρ is the density required, and dV/dh the vertical potential gradient.

The value of ρ varies greatly, but through much of the atmosphere the convection current is of the order 10^{-16} ampere per square centimeter cross section of the wind, per meter/second velocity.

(*d*) Conduction current, due to the downward flow of one set of ions, usually the positive, and the simultaneous upward flow of the other in response to the vertical potential gradient. The density of this current, or strength per square centimeter cross section, may be computed from the potential gradient and the conductivity, or, with suitable apparatus, may be measured directly. The average value of this conduction current is of the order of 3×10^{-16} ampere per square centimeter of, apparently, the entire surface of the earth. It generally is less during the day than at night, and less in summer than winter; but always of such value that the sum total of the current for the entire earth is roughly 1500 amperes. How this constant current, always, on the whole, in the same direction, is maintained is one of the greatest problems of atmospheric electricity.

RADIOACTIVE CONTENT OF THE ATMOSPHERE

The first evidence that the atmosphere normally contains one or more radioactive substances was obtained in 1900 when Geitel[152] and C. T. R. Wilson [153] independently found than an insulated electrified conductor gradually loses its charge even when inside a closed vessel. Later Elster and Geitel[154] showed that a bare wire exposed to the air and charged negatively to a high voltage gradually becomes coated with radioactive material. In 1904 Bumstead[155] showed that the radioactive substance of the atmosphere consists essentially of radium and thorium emanations, which, it is now known, occur in widely varying propor-

[152] *Phys. Zeit.*, **2**, p. 116, 1900.
[153] *Proc. Camb. Phil. Soc.*, **2**, p. 52, 1900.
[154] *Phys. Zeit.*, **2**, p. 590, 1901.
[155] *Amer. Jr. Sci.*, **18**, p. 1, 1904.

tions. On the average, however, they appear to produce about the same amount of ionization, that is, near the surface and over land, roughly 2 ions each, of each sign, per cubic centimeter per second.

The emanations, which are heavy, radioactive gases, are several fold more abundant in mines and cellars than in the open and obviously get into the atmosphere by diffusion from the earth where they are generated by the spontaneous decomposition of radium and thorium. They may be absorbed from a known volume of air by coconut charcoal, liquified by low temperatures (−150° C. or lower), or caught up by a conductor charged to a high negative potential. In any case the nature of the deposit can be determined from the decay curve, from which, together with the saturation current and the volume of air used, the amount of active material per unit volume may be determined. In this way it has been found[156] that the radioactive emanations in the atmosphere over the Pacific Ocean, Sub-Antarctic Ocean, and land (average) amount to 3.3×10^{-12}, 0.4×10^{-12}, and 88×10^{-12} curie per cubic meter, respectively. Or, since the volume of one curie of emanation at standard temperature and pressure is 0.59 cubic millimeter,[157] the emanation gases constitute, in these several regions, 1.95×10^{-19}, 0.24×10^{-19}, and 51.9×10^{-19} of the atmosphere, respectively.

The amount of these emanations appears to be sufficient to account for the measured ionization (ions of molecular size) on the land, but quite insufficient over the oceans to maintain the ionization of these regions. Perhaps, as the slow ions are so very numerous over land areas, it may account for only a small part of the ionization in either case.

PENETRATING RADIATION

It has been found that the air within a closed metallic vessel remains fully conductive, even when deprived of all emanations and when the inner walls of the vessel have been cleaned, as far as possible, of radioactive materials. By surrounding this vessel with thick screens, or sinking it in water, the conductivity of the

[156] Bauer and Swann, Publication 175 (Vol. III) Carnegie Institution of Washington, p. 422.

[157] Rutherford, "Radioactive Substances and Their Radiations," Cambridge University Press, 1913, p. 480.

enclosed air is more or less reduced.[158] It is, therefore, inferred that the conductivity in question is produced by penetrating radiation of the γ type from the outside. One obvious source of such radiation is the radium and thorium, and their decomposition products, that seem to be more or less prevalent everywhere near the surface of the earth, especially over land.

That a portion at least of the ionization giving this conductivity is produced by the γ rays of ordinary radioactive substances in the earth and lower atmosphere is evident from the fact that it decreases with elevation up to about 1.5 kilometers above the surface. From this level, however, up to the greatest elevation at which it has been reported, 9 kilometers, the ionization increases very rapidly, and to several fold its surface value.[159] Hence there appears also to be a γ radiation of extremely high penetrating power that enters the lower atmosphere from somewhere above it.

ORIGIN AND MAINTENANCE OF THE EARTH'S CHARGE

Numerous hypotheses have been made to account for the negative charge of the earth and to explain how that charge is maintained in spite of the conductivity of the atmosphere, but no satisfactory explanation of either has yet been found. As Simpson[160] has explained, since the vertical current is constant up to at least 1800 meters, the greatest altitude at which it has been determined, it follows that the negative charge of the earth can not be supplied from the air below that level. Neither can it be supplied by electrical separation within the earth, as that would quickly lead to a positive instead of the prevailing negative surface charge.

Simpson[161] suggests that the negative charge of the earth may be maintained by a bombardment from the upper atmosphere, or even cosmical space, of negative ions of much greater penetrating power than any now known. But, it is stated, this is only a suggestion and not a solution of the greatest, perhaps, of the problems of atmospheric electricity.

---

[158] Rutherford and Cook, *Phys. Rev.*, **16**, p. 183, 1903; McLennan and Burton, *Phys. Rev.* **16**, p. 184, 1903.

[159] Kolhörster, *Deutsch. Phys. Gesell.*, **16**, p. 719, 1914.

[160] *M. W. R.*, **44**, p. 115, 1916.

[161] *Loc. cit.*

The latest and most satisfactory explanation of the origin of the earth's charge is the following, by Swann[162]:

"Measurements of the variation of the penetrating radiation, with altitude, point to the upper atmosphere as the origin of a part of this radiation. The whole of the penetrating radiation is probably of the γ-ray type, but the part which reaches the earth's surface from the outer atmosphere is naturally the most penetrating part. Indeed, it is so penetrating that it passes through a thickness of air which would be equivalent, in absorptive action, to a column of mercury 76 cm. high, if absorption coefficients were simply proportional to density and were independent of material. The γ-ray radiation from the outer layers of the atmosphere will consequently be very 'hard,' and, in accordance with the known results of laboratory experiments, we must conclude that the negative corpuscles which it emits from the air molecules are emitted almost entirely in the direction of the radiation, and further, that they can have a range in air at least equal to that of the swiftest β-rays from radium products, a range, for example, of 8 meters. The emission of corpuscles by these γ-rays will consequently result, at each point of the atmosphere, in a downward current of negative electricity, which we shall call the corpuscular current. This corpuscular current will charge the earth until the return conduction-current balances the corpuscular current at each point of the atmosphere.

"Taking, for the purpose of this abstract, a simplified case where the penetrating radiation considered is all directed vertically downwards, if q is the number of corpuscles liberated per c.c. per second by the penetrating radiation and h the average distance which a corpuscle travels from its point of origin, the corpuscular current density will be

$$i = qeh,$$

where e is the electronic charge.

"If q be taken as 2, which is probably about equal to the number of pairs of ions produced per c.c. per second in a closed vessel as a result of the part of the penetrating radiation in question, and if h be taken as 8 meters, we have

$$i = 2 \times 4.8 \times 10^{-10} \times 800 = \text{about } 8 \times 10^{-7} \text{ E. S. U./cm.}^2,$$

[162] *Phys. Rev.*, 9, p. 555, 1917.

which is just of the order of magnitude of the air-earth current density, so that on this view, the penetrating radiation from the outer layers of the atmosphere provides a sufficient basis for the explanation of the maintenance of the earth's charge.

"The corpuscular current-density, and consequently the conduction current-density, will not necessarily be independent of the altitude, for the factors upon which i depends, viz., the intensity and quality of the penetrating radiation, the number of molecules per c.c. available for possible ionization by the radiation, and the range of the corpuscles set free all alter with the altitude.

"A few minor difficulties present themselves if the above view be adopted. Thus, for example, near the surface of the earth, a considerable portion of the whole penetrating radiation comes from the soil, and is directed upwards, but this difficulty disappears when it is remembered that the average 'hardness' of the radiation from the soil is very much less than that of the radiation which reaches the earth from the outer layers of the atmosphere. Again, it might appear that the corpuscles set free by the pentrating radiation should, on account of their great energy, produce in the atmosphere many more ions per second than are actually found to be produced. This difficulty, and others of allied nature become greatly reduced in magnitude, however, when considered in the light of our present knowledge of the action of very swift β-rays when passing through a gas."

(To be concluded.)

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY*

THE NATURE OF A DEVELOPER SLUDGE.[1]

By Mr. J. I. Crabtree.

[ABSTRACT]

A SAMPLE of a sludge taken from a deep tank pyro developer compounded with sodium bisulphite was found to consist mainly of fine needle shaped crystals of calcium sulphite corresponding to the formula $CaSO_3\ 2H_2O$.

In order to explain the presence of the calcium salt it was at first assumed that some compound of calcium had been accidentally added to the developer, or that some of the ingredients contained calcium as impurity, but as only pure chemicals were employed it was concluded that the calcium must have been originally present in the water used for compounding the developer.

On adding a definite amount of calcium in form of chloride or sulphate to water used for mixing the developer, it was found that the presence of .025 per cent. dry calcium chloride was sufficient to assure the formation of crystals of calcium sulphite, if the solution containing the sulphite and bisulphite was allowed to stand before adding the carbonate.

Calcium sulphite is soluble in an excess of sodium bisulphite forming calcium bisulphite, but on allowing this solution to stand in the air needle shaped crystals of $CaSO_3\ 2H_2O$ are deposited.

The absence of magnesium from the sludge in question was due to the relatively high solubility of magnesium sulphite and magnesium carbonate in a solution of sodium carbonate.

Although a number of trials were made by compounding the complete developer with water containing calcium salts, in no case were needle shaped crystals deposited on standing, only a semi-amorphous sludge being precipitated. It was considered

*Communicated by the Director.

[1] Communication No. 62 from the Research Laboratory of the Eastman Kodak Company, published in *British Journal of Photography*, 1918, p. 87.

that the needles could only have crystallized within the complete developer if it were very warm.

The presence of a sludge such as the above in a developer is harmless if allowed to settle, though the developer is robbed of sulphite to the amount required to form the sludge. If the developer is agitated, the sludge is apt to cause trouble by settling on the emulsion of the plates or films, though it may be removed by filtering.

In case the calcium is present as bicarbonate, thus causing temporary hardness of the water, the formation of the sludge may be prevented by boiling the water and allowing it to cool previous to compounding the developer. If the calcium is present as chloride, or sulphate, in which case the water is permanently hard, this may be removed by precipitating with sodium or potassium oxalate or sodium carbonate. The oxalate treatment will also remove temporary hardness.

Tests showed that the oxalate had no effect on the fogging power of the developer when present even to the extent of 1 per cent., so that a little excess of oxalate during precipitation will do no harm.

Mica Schist for Furnace Lining. G. F. LOUGHLIN. (*U. S. Geological Survey.*)—Mica schist is one of the commonest kinds of metamorphic rock and consists essentially of mica and quartz, with which may be associated certain other minerals, such as garnet and staurolite. Owing to its marked foliation, its softness, and its generally unattractive appearance, it has not been greatly used as structural stone or as paving or crushed stone. It was once quarried near Bolton, Conn., for use as flagstone, but it was too soft to withstand the wear upon it in places of much travel.

The mica, to which the softness of mica schist is due, however, successfully withstands a very high temperature, and as the stone can be readily cut into blocks of the desired shape, mica schist has therefore been used considerably as furnace lining. The mica schist quarried for this use is found in eastern Pennsylvania, at places conveniently near the metallurgical plants in which it is required. The quantity of mica schist produced for this purpose in 1917 was 39,975 short tons, an increase of 6739 tons, or 20 per cent., over 1916. The value of the output in 1917 was $85,986, an increase of $38,682, or nearly 82 per cent. The greater increase in value was due to a rise in price from $1.42 to $2.15 a ton, which largely represents the increased cost of production.

NOTES FROM THE RESEARCH LABORATORY WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY*

THE ACTION OF REDUCING GASES ON HOT SOLID COPPER.

By Norman B. Pilling.

THE deterioration in mechanical strength experienced by copper containing disseminated oxide after heating in contact with reducing gases is marked; a copper strap, initially ductile and resistant to repeated bending, after exposure of this kind becomes weak and friable, breaking when an attempt is made to bend it. Copper straps heated in atmospheres of hydrogen, carbon monoxide and natural gas all developed this defect, the severity of this action depending on the nature of the reducing gas. In the case of hydrogen the first mechanical effects of the deterioration appear between 400 and 500°C, and at temperatures above 700°C the action is very rapid, a few minutes' exposure being sufficient to ruin the strap.

Deoxidation alone cannot account for the weakness developed, for it is hard to see why the substitution of a small void for a small particle of very brittle cuprous oxide would weaken the surrounding copper. The action taking place appears to be that hydrogen, if physically soluble in the copper, would diffuse into the metal, attack and reduce the grains of cuprous oxide with the formation of steam. If steam is physically less soluble in solid copper, the net result of the reaction would be the formation of a quantity of steam free within the voids left by the reduction of the cuprous oxide and at some considerable pressure. The combination of this pressure with the known intercrystalline weakness of copper at high temperatures would force the individual grains apart until relief is obtained, and the resultant weakness be due simply to the lack of mechanical coherence within the "puffed" copper. Microscopic examination of copper after this treatment disclosed

*Communicated by the Director.

intercrystalline fractures, and the swelling action accompanying their formation increased the physical dimensions of the copper piece.

To verify the explanation given, the diffusion of hydrogen, steam, carbon monoxide and carbon dioxide through copper was measured. A thin walled copper tube extended through a quartz tube filled with the desired gas, and the changes in pressure within the previously evacuated copper tube were measured with an optical-lever manometer. At 700°C the following comparative rates were obtained, referred to hydrogen as 1000:

Gas	Diffusion rate
H_2	1000
H_2O	65
CO	17
CO_2	0.6

With hydrogen the first considerable diffusion began between 400 and 500°C, corresponding to the initial deterioration in physical quality noted. Measurements of the rate of diffusion of hydrogen were also made by noting the depth to which the reduction of the oxide had occurred in solid pieces of copper. By this method diffusion was also found to become active between 400 and 500°C.

The distribution of the oxide particles in copper is a more important factor than their total quantity. In wrought copper the particles are uniformly dispersed throughout the grains, and only those lying by chance at the grain boundaries are operative in forming intercrystalline fractures. Cast copper, in which the oxide is segregated as a eutectic at the grain boundaries, is extremely susceptible to hydrogenation.

CHANGE OF SPECIFIC INDUCTIVE CAPACITY WITH TEMPERATURE AND IMPREGNATION IN PAPER.

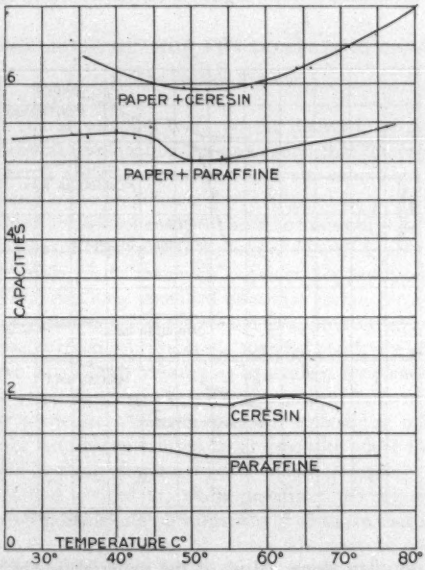
By H. C. P. Weber and T. C. MacKay.

THE object of this work was to obtain preliminary information on a number of materials. The first measurements were made by a substitution form of series resistance method, with high frequency generator and telephone. Silence in telephone was diffi-

cult to obtain due to harmonics. An Einthoven galvanometer proved less sensitive to changes in the resistance and the eye strain in the detection of very small currents is great.

In order to make a large number of measurements to determine quickly the order or magnitude of the specific inductive capacities, the simple bridge method in which two arms are resistances and the other two capacities was used. In this bridge R_1 and R_2 each

FIG. 1.

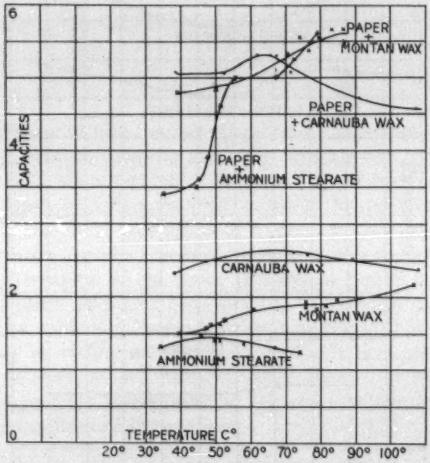


are 9000 ohms, C_s is the condenser containing the sample, and C a calibrated air condenser. The sample holder consisted of two massive iron electrodes kept at a definite separation by small glass stops. The capacity of the sample holder as an air condenser was calculated from the dimensions to the 0.000185 m. f. and found by measurement to be 0.000202. Temperatures were taken as those of the massive iron container.

In the cases where impregnated paper was measured three layers 0.0015 inch thick were used. Impregnation changed the thickness of the paper 10–35 per cent., depending upon the nature of the substance. This change was measured where possible. In the case of dielectric without paper the thickness of the layer was about 0.01 inch, *i. e.*, that of the glass stops.

The curves in Figs. 1 and 2 show the values obtained with varying temperature. The specific inductive capacities of all of the substances tried is much higher in conjunction with the impreg-

FIG. 2.



nated paper than alone. Most of the materials show a decided change in the neighborhood of the melting point. The two hydrocarbons—paraffin and ceresin—show little change alone; in paper a decided minimum is shown, with a gradual rise beyond the melting point. For the acids and acid derivatives—Carnauba wax, montan wax and ammonium stearate—there is again an appreciable difference between the values for pure substance and substance with paper. The values for pure material are, however, influenced

less by temperature changes. In the paper-impregnated samples there is a maximum or a decided hump in the curve.

In general a very decided change in the specific inductive capacities of materials is seen to accompany change of state of materials. The direction of the change seems to bear a definite relation to the composition. Further work would seem desirable along this line in order to determine the cause of this behavior.

A NULL BALLISTIC METHOD FOR COMPARING CAPACITIES.

By Dr. Phillips Thomas.

IN the course of some work on the dielectric properties of various chemical combinations, it was found that the preparation of more than a few cubic centimeters of the compound was undesirable until some preliminary knowledge of its properties had been obtained. Consequently, it became necessary to measure with fair accuracy capacities of the order of 10^{-9} to 10^{-11} farads.

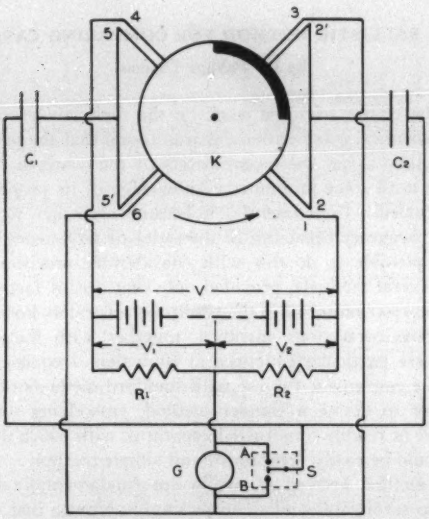
It is possible to do this with considerable precision by any one of several methods, provided only that certan factors which enter as correction terms in the results be accurately known. The troublesome corrections involved, together with the fact that values were particularly desired at equivalent frequencies lower than those convenient for use with standard methods of test, led the writer to devise a simpler method, embodying only easily obtainable or readily constructed apparatus, with which the corrections should be easily determined and simple to apply.

The method arrived at, while not fundamentally new, has proved so serviceable and so surprisingly accurate that it is here offered for the consideration of others who may be confronted with similar problems.

The idea of measuring the absolute capacity of a condenser by the discharge through a ballistic galvanometer of a single impulse from the condenser is well known. So also is the modification in which the single impulse is replaced by a train of similar impulses produced by some form of commutator which permits only the charge or the discharge impulses, but not both, to reach the galvanometer. The capacity is given in terms of the current figure

of merit or sensitivity of the galvanometer, the charging voltage and speed of the commutator. This method is applicable to very small capacities if the available charging voltage is sufficiently large. There remains, however, the difficulty of measuring accurately the commutator speed and the charging voltage, also the added and somewhat troublesome one of keeping both speed and voltage constant; also the galvanometer must be checked at

FIG. 1.



frequent intervals, and finally all the disadvantages of a deflection method are present.

The present method is a modification of the above, in which the train of impulses from one condenser is balanced by a second train from a different condenser, passing through the galvanometer in the opposite direction. The apparatus and connections are shown in Fig. 1, in which K is the commutator, rotating counter clockwise as shown; C_1 is the condenser to be measured, C_2 a known condenser, usually a standard subdivided microfarad, R_1

and R_2 are standard dial rheostats. The commutator presents an insulating surface to the four sets of brushes, numbered 1 to 6, except for the solid segment, which latter is metal. The angle of the solid segment is 89°, and the brushes are set in pairs on 90° lines, so that no two pairs of brushes are ever interconnected.

As the commutator revolves it connects together in sequence, brushes 1 and 2, 2 and 3, 4 and 5, 5 and 6, and so on. If the switch S is closed in position A, the following cycle is completed once every revolution of the commutator. Left hand numbers indicate brushes connected.

1, 2 (1)–Condenser C_2 is charged to a voltage V_2, equal to $\frac{VR_2}{R_1+R_2}$

2′, 3 (2)–Condenser C_2 is discharged through the galvanometer, G.

4, 5 (3)–Condenser C_1 is charged to a voltage V_1, equal to $\frac{VR_1}{R_1+R_2}$

5′, 6 (4)–Condenser C_1 is discharged through the galvanometer in the opposite direction to that of the discharge from C_2.

Since the directions of the discharge impulses from C_1 and C_2 through the galvanometer are opposite, there will be no permanent deflection of the galvanometer light spot if the discharge impulses are equal. This condition is realized when R_1 and R_2 are so adjusted that

$$NC_1V_1 = NC_2V_2$$

or, since V_1 and V_2 are proportional to R_1 and R_2,

$$\frac{C_1}{C_2} = \frac{R_2}{R_1} \qquad (1)$$

By throwing switch S into position B the galvanometer receives the charge impulses instead of those of discharge. In testing samples, a balance is obtained for both charge and discharge; a difference of more than one per cent. between the indicated capacities shows that the results are not accurate to one per cent., due to different relative amounts of absorption, leakage, or both, in C_1 and C_2.

The result given by equation (1) is the comparative value of the total capacity in branches C_1 and C_2. This value must be corrected for the small permanent capacity in the two branches, when the condenser C_1 and C_2 are disconnected. The use of a large condenser on the C_2 side enables one to neglect this correction

on that side; the correction for C_1 is easily applied by disconnecting C_1, obtaining a balance, and subtracting the indicated capacity from that found when C_1 is connected. Thus,

$$C_1+c_1=\frac{C_2R_2}{R_1} \qquad C_1 \text{ connected}$$

hence $$c_1=\frac{C_2r_2}{r_1} \qquad C_1 \text{ disconnected}$$

$$C_1=\frac{C_2R_2}{R_1}-\frac{C_2r_2}{r_1}$$

If C_2 equals c_2, and R_1 equals r_1, we have

$$C_1=\frac{C_2}{R_1}(R_2-r_2) \qquad (2)$$

which enables the correction to be made by simply subtracting the value of R_2 found with C_1 disconnected from that found with C_1 connected, and using the remainder in equation (1).

Obviously, the commutator speed for any capacity must not be high enough to prevent full charge from entering the condensers during one charging interval. Fortunately, satisfying this condition for C_1 also does so for C_2, because the resistance in the charging circuits are R_1 and R_2, and the two time constants, R_1C_1 and R_2C_2 are equal by equation (1), when balance has been established. This condition, however, sets an upper limit to the product NCR; in practice the maximum permissible speed corresponding to the desired product RC is taken from a curve kept with the apparatus.

The upper limit in capacity or voltage is set by the appearance of strong forced vibrations of the galvanometer moving system, due to the fact that the charging or discharging impulses, while equal, do not reach the galvanometer at the same instant, but are spaced a half revolution apart. The accuracy obtainable is of course decreased when the light spot is thus broadened out into a band of light. The lower limit of accuracy is set by the relative values of the residual or permanent capacity in the C_1 branch, and the capacity being measured.

The method is very easy to use, and its sensitiveness is limited only by the current sensitivity of the galvanometer. Small frictional voltages induced by the rotation of the commutator prevent the use of the most sensitive galvanometers obtainable, but a galvanometer of sensitivity 10^{-9}, current, is good in this respect and

sufficiently sensitive to measure 10^{-10} farad of capacity to one per-cent. on a few volts.

The fact that neither voltage nor speed enters into the equation giving the results, makes it possible to obtain curves of variations of capacity with voltage and with equivalent frequency, since in most cases these coefficients of change are small, and one need not employ means for either closely controlling or very accurately reading either speed or voltage.

Neither the sensitiveness nor the accuracy is affected by the relative magnitude of C_1 and C_2, assuming that R_1 and R_2 are accurate over any range desired. Hence very small condensers may be compared directly with a large standard subdivided microfarad, in order either to calibrate the small or the large condenser. This is a great advantage and is possessed by none of the standard methods of testing. The writer uses, commonly, fixed values for C_2 and R_1, of 0.05 microfarad and 5000 ohms respectively, resulting in the convenient equation

$$C_1 = 10^{-11} (R_2 - r_2)$$

Rheostat R_2 has dials giving 10 x 0.1 and 9 x (1+10+100+1000). With C_1 disconnected the galvanometer is sensitive to one division on the 0.1 ohm dial with an e.m.f. (V) of 10 volts, and the balance gives

$$C_1 = 5.4 \times 10^{-11} \text{ farads}$$

as the C_1 residual. Hence if one per cent. accuracy must be attained, 10^{-10} farad is the lower limit of capacity which can be measured.

A new commutator is now being built, having two segments each 45° long instead of one of 90°. With this will be used brushes set in pairs at 45° instead of 90°. This will cause Q_1 and Q_2 to reach the galvanometer at the same time, and will thus do away entirely with the forced vibrations of the moving system.

It has been found that with certain modifications, this apparatus may be used to measure the insulation resistance of samples as well as their capacity. It seems probable also that the effects of dielectric polarization and absorption on both resistance and capacity may at least be estimated, if not measured quantitatively. This work is now in progress, and the results will be embodied in a later paper.

Metal Cutting with the Electric Arc. G. KEARNEY. (*General Electric Review*, vol. xx, No. 11, November, 1917.)—While the possibilities of the electric arc as a cutting instrument have been generally recognized as a sort of a by-product of its principal function as a welding medium, there seems to be a considerable field in which apparatus designed for electrical welding can be successfully exploited primarily for cutting purposes. Some data have been compiled regarding cutting speeds, but there appears to be a lack of specific information as to the actual process.

Some tests have been made with a 30-kilowatt, 60-volt standard arc welding set installed in a small rolling mill. The set has as yet been in operation only a short time, but sufficient work has been done to demonstrate the value of the method. The mill is at present engaged in working up scrap iron and steel into standard shapes. The scrap metal is cut to suitable size and weight before being placed in the furnace for conversion into billets. The electric cutting apparatus was installed for cutting the considerable quantity of scrap which is too large to be handled by shears. This consists chiefly of plates of various sizes and thicknesses, shafting, bars, rails, etc.

In cutting, as in welding, the positive lead of the direct-current generator is connected to the piece to be cut, while the negative lead is connected by means of a suitable holder to a carbon electrode. A contact is made between this carbon and the work, and in breaking this an arc is formed which almost instantly melts the metal where it strikes. The molten metal is allowed to run off and the arc moves slowly along the work, forming a well-defined cut. No great skill is required in the manipulation of the arc, as when once formed it is fairly stable, and with a properly shaped electrode it can be controlled with a considerable degree of accuracy. A particularly attractive field for this apparatus is in cutting steel plates where accuracy or a sharply defined edge is not essential. For cutting a $^{9}/_{16}$ plate, the cost of cutting was found to be 6½ cents per foot, including all charges. The actual average speed of cutting was 2.78 minutes per foot, and the total time per foot was 4.07 minutes.

A word of caution is necessary to those unfamiliar with the physiological effects of the electric arc. Great care should be exercised by the operator to avoid accidentally striking the arc without having the face and eyes protected by a mask or shield, and the hands and arms protected by heavy clothing, or preferably by leather. Exposure of the skin to the rays of the arc results in painful burning similar to a severe sunburn, and the rays from the arc cause a very painful inflammation of the eyes.

THE FRANKLIN INSTITUTE.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Coates, Jesse, Major	American Expeditionary Force	France
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R I

Name and rank	Branch of service	Location
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major.	War plans division, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Private	437th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yoeman, 1st class	U. S. Naval Reserves	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York

Name and rank	Branch of service	Location
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major		Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.

Name	Appointment	Location
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Cope, Thomas D.	National Research Council	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dickie, G. W.	Chief Inspector, U. S. Shipping Board, Moore & Scott Shipyard	Oakland, Calif.
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lenher, Victor, Major	Chemical Service Section, N. A.	Washington
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York

Name	Appointment	Location
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member of Council of National Defense	Philadelphia
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

NECROLOGY.

William Houston Greene, A.M., M.D. The news of the sudden death of Dr. William H. Greene at his summer home in Wenonah, N. J., on August 8th came as a shock to his many friends in Philadelphia and elsewhere. Aged 64 years he looked back on a long and successful career as an educator, chemist and business man, and for many years he had played a prominent part in the scientific, artistic and financial life of our city. His membership in the Franklin Institute dated from August 2, 1884, and it was during the first decade of it that he took an active interest in the affairs of the Institute. During the years 1887–1889 he was a member of the Committee on Science and the Arts, from 1891 to 1892 Vice President and in 1893 President of the Chemical Section. He contributed a number of papers on chemical subjects to the Journal of the Institute, and the library is indebted to him for numerous and valuable gifts.

Doctor Greene was born at Columbia, Pa., on December 30, 1853. When he was a boy his parents moved to Philadelphia, and it was here that he received the greater part of his education. After completing the grammar school course he entered the Boys' Central High School, from which he graduated in June, 1870. Among the members of his class quite a number subsequently attained distinction in various professions, and two of these, Dr. Elihu Thomson and Prof. Henry Willis, were to become his most intimate and

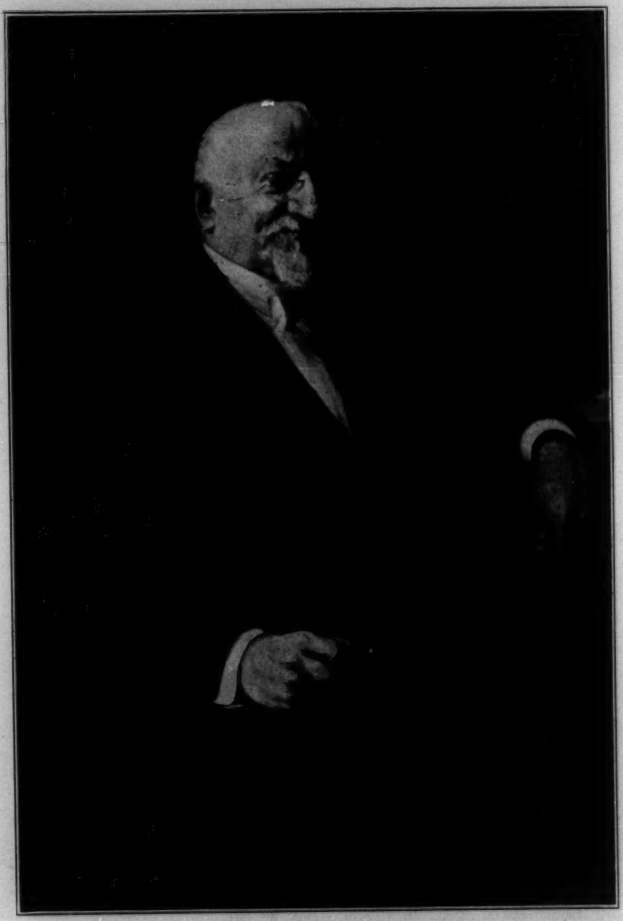
life-long friends. Shortly afterwards he matriculated in the Jefferson Medical College, where his pronounced scientific bent led him to specialize in chemistry, and after receiving the degree of Doctor of Medicine from this institution in 1873 he was appointed assistant to B. Howard Rand, who held the chair of chemistry at that time. Two years later he was advanced to the position of Demonstrator of Chemistry.

While there is no doubt that Dr. Greene's work in this position met all requirements, he seems to have felt certain gaps in his training as a chemist, particularly in the field of organic chemistry. So he decided to go abroad and, attracted by the great fame of Adolphe Wurtz, he went to Paris in 1877 and there spent two years in fruitful experimentation and research under the direction of the great teacher, and in close companionship with distinguished chemists like Friedel, Le Bel and Henninger. After his return to this city he became Demonstrator of Chemistry in the Medical School of the University of Pennsylvania, and a year later was elected Professor of Chemistry in the Central High School, which position he held until 1892. It was in this period of twelve years that Dr. Greene achieved his greatest successes as a chemist and teacher. Esteemed and beloved by his students and his associates in the Faculty, he originated and developed methods of instruction that proved most successful, especially along the lines of lecture demonstration and laboratory practice. The Central High School was among the first, if not actually the first, of our secondary schools in which regular laboratory exercises by the students were a part of the instruction in chemistry. It may be admitted that the work of Dr. Greene in this direction was preceded by that of his friend, Elihu Thomson, in the same school, but it was he who first equipped a laboratory with desks, water and gas supply, reagents, etc., for the individual student, and devised a complete course of experiments. During these years also Dr Greene conducted a considerable number of original researches of which the appended bibliography[1] will show the scope. Among the most important of these his work with Dr. William H. Wahl on the reduction of manganese, and that with Dr. Samuel C. Hooker on lapachic acid and its numerous derivatives may be mentioned. A large collection of fine and rare specimens of organic compounds made by Dr. Greene and now in the possession of the Central High School bears witness to the skill and the industry with which he devoted himself to synthetic chemical work. His masterly translation of Wurtz's Elementary Lessons in Modern Chemistry and his own excellent text-book Lessons in Chemistry have both passed through many editions, of which the more recent were edited and revised by H. F. Keller.

As a consulting chemist Dr. Greene long enjoyed an enviable reputation, his experience extending over a wide range of subjects in medical and industrial chemistry.

In 1892 he resigned his professorship to associate himself with his father, the late Stephen Greene, in the printing business. Since then, and

[1] The writer is indebted for this bibliography to Mr. Alfred Rigling, Librarian of the Institute.



WILLIAM HOUSTON GREENE
From the painting by Frank B. A. Linton

particularly since his father's death in 1908, he devoted himself to the extension of the great printing plant, while he also gave liberally of his time and means to the advancement of the musical and artistic life of Philadelphia. That he still retained a vivid interest in the progress of science is well known to his surviving friends, as well as to many a young and struggling inventor who, through his encouragement and financial aid, has been enabled to develop and make a success of some practical application of a scientific principle.

Among the learned societies of which Dr. Greene was a member are the American Philosophical Society, the Chemical Societies of London, Paris and Berlin, the American Association for the Advancement of Science, the Philadelphia County Medical Society, and many others. At the time of his death he was President of the Philadelphia Musical Art Club.

Dr. Greene was a man of sterling character. Outspoken in his opinions he had a profound contempt for all sham and affectation. Among his most pronounced traits were his sociable disposition and his generosity. His contributions to various charities and his gifts to individuals whom he believed to be in need were innumerable, yet he hardly ever spoke of them even to his intimate friends. Among the bequests he made to institutions of learning were those of his unique and most valuable chemical library to Jefferson College, of $2000 to the American Philosophical Society for its publication fund, and of a large part of his chemical apparatus and collection to the Central High School. On the largest scale his beneficence was exemplified by the bountiful contributions he made to the American Red Cross, the Pelgian Relief Committee, and indeed to every war charity that appealed to his warm and loyal heart.

HARRY F. KELLER.

BIBLIOGRAPHY.

PAPERS BY DOCTOR GREENE.

1877

Nouveaux modes de formation de l'oxyde d'éthyle. Paris, *Acad. Sci. Compt. Rend.*, **85**, 624.

1878

Décomposition de l'alcool par le chlorure de zine à de hautes températures. Paris, *Acad. Sci. Compt. Rend.*, **86**, 1140; Paris, *Soc. Chim. Bull.*, **29**, 457.

Liquefaction of Oxygen. FRANK. INST. JL., **105**, 119.

Neue Bildungsweise von Aethylenoxyd und Aethyläther. *Journ. f. Prakt. Chemie*, **126**, 208.

Nouveaux modes de formation de l'oxyde d'éthyle. Paris, *Acad. Sci. Compt. Rend.*, **86**, 1141; Paris, *Soc. Chim. Bull.*, **29**, 458.

Sur la formation de l'hexaméthylbenzine par la décomposition de l'acétone. Paris, *Acad. Sci. Compt. Rend.*, **87**, 931.

Zersetzung des Aethylalkohols durch erhitztes Chlorzink. *Journ f. Prakt. Chemie*, **125**, 352.

1879

Nitrite of Amyl. *Amer. Jl. Pharm.*, **51**, 65.

On dioxyethyl-méthylène, and the préparation of méthylène chloride. *Amer. Phil. Soc. Proc.*, **18**, 346.

On the formation of dibenzyl by the action of ethylene choride on benzol in the presence of aluminum chloride. *Amer. Phil. Soc. Proc.*, **18**, 345.

Sur la formation de l'hexaméthylbenzine par la décomposition de l'acétone. Paris, *Soc. Chim. Bull.*, **32**, 422.

Sur le dioxyéthyl-méthylène et sur la préparation du chlorure de méthylène. Paris, *Acad. Sci. Compt. Rend.*, **89**, 1077.

Ueber die Entstehung von Hexamethylbenzol aus Aceton. *Journ. f. Prakt. Chemie*, **127**, 336.

1880

On a new synthesis of saligenin. *Amer. Phil. Soc. Proc.*, **18**, 451.

On the action of hydrochloric acid and of chlorine on acetobenzoic anhydride. *Amer. Phil. Soc. Proc.*, **19**, 13.

On the preparation of methylene chloride, and dioxyethyl-methylene. *Chem. News*, **42**, 7.

Sur l'anhydride acétobenzoïque. Paris, *Soc. Chim. Bull.*, **33**, 424.

Sur la préparation des dérivés iodés et bromés de la benzine. Paris, *Acad. Sci. Compt. Rend.*, **90**, 40.

Sur une nouvelle synthèse de la saligénine. Paris, *Acad. Sci. Compt. Rend.*, **90**, 40.

1881

On a new synthesis of saligenin. *Amer. Chem. Jl.*, **2**, 19.

On the action of hydrochloric acid and of chlorine on acetobenzoic anhydride. *Amer. Chem. Jl.*, **2**, 96.

Sur la préparation des dérives iodés et bromés de la benzine. Paris, *Soc. Chim. Bull.*, **36**, 234.

Sur une nouvelle synthèse de la saligénine. Paris, *Soc. Chim. Bull.*, **36**, 241.

1883

Sur une nouvelle forme d'uréomètre. Paris, *Acad. Sci. Compt. Rend.*, **97**, 1141.

1884

On dioxyethyl-methylen, and the preparation of methylen chloride. *Chem. News*, **50**, 75.

Sur une nouvelle forme d'uréomètre. Paris, *Soc. Chim. Bull.*, **42**, 252.

1885

Some remarks on Dr. Doremus' simple apparatus for the rapid estimation of urea. *Amer. Chem. Soc. Jl.*, **7**, 166.

Sur le dioxyéthyl-méthylène et sur la préparation du chlorure de méthylène. Paris, *Soc. Chim. Bull.*, **43**, 81.

1886

Réclamation de priorité sur la préparation du dioxyéthyl-méthylène. Paris, *Soc. Chim. Bull.*, **45**, 164.

1889
On aceto-metanitrobenzoic anhydrides. FRANK. INST. JL., 128, 64.
Sealing of volatile liquids in glass tubes. FRANK. INST. JL., 127, 69.
1900
Prismatic lighting for the illumination of dark interiors. FRANK. INST. JL., 150, 97.

WITH SAMUEL C. HOOKER.

1889
Constitution of lapachic acid and its derivations. FRANK. INST. JL., 128, 142.
Lapachic acid in bethabarra wood. FRANK. INST. JL., 127, 387.
Ueber die Constitution der Lapachosäure und ihrer Derivate. Berlin, *Chem. Ges. Ber.*, 22, 1723.
1891
On some derivatives of lapachic acid. FRANK. INST. JL., 131, 56.

WITH J. A. LE BEL.

1878
Action du chlorure de zinc sur l'alcool méthylique; hexaméthylbenzine. Paris, *Acad. Sci. Compt. Rend.*, 87, 260; Paris, *Soc. Chim. Bull.*, 30, 50.
Nouveau mode de préparation du diméthyl-éthylène normal. Paris, *Soc. Chim. Bull.*, 29, 306.
1879
Réaction du chlorure de zinc sur l'alcool butylique normal. Paris, *Acad. Sci. Compt. Rend.*, 89, 413.
1881
On the decomposition of alcohols, etc., by zinc chloride at high temperatures. *Amer. Chem. Jl.*, 2, 20.
Réaction du chlorure de zinc sur l'alcool butylique normal. Paris, *Soc. Chim. Bull.*, 35, 438.

WITH A. J. PARKER.

1879
Note on hyraceum. *Phila. Acad. Nat. Sci. Proc.*, 31, 12.

WITH WILLIAM H. WAHL.

1890
Alloys of sodium and lead. FRANK. INST. JL., 130, 483.
1893
A new method of reducing metallic oxides. FRANK. INST. JL., 135, 453.
New process for manufacture of manganese on the commercial scale. FRANK. INST. JL., 135, 218.

LIBRARY NOTES.

PURCHASES.

Chemical Society of London.—Annual Reports on the progress of Chemistry, vol. 14. 1917.
Gisholt Machine Co.—Turret Lathe Guide. 1917.

HERINGTON, C. F.—Powdered Coal as a Fuel. 1918.
MITCHELL, C. A.—Edible Oils and Fats. 1918.
Moody's Manual of Railroad and Corporation Securities. 1918.
MORGAN, G. T.—Organic Compounds of Arsenic and Antimony. 1918.
SHEPPARD, S. E., and MEES, C. E. K.—Investigations on the Theory of Photographic Process. 1907.
SMITH, BERTRAM.—Bombs and Hand Grenades—British, French and German. 1918.
Who's Who in America, vol. 10. 1918–1919.

BOOK NOTICES

CHIMIE ET INDUSTRIE. Under this title, the newly-formed French Society of Industrial Chemistry, that has begun very auspiciously, will publish a monthly journal, the first number of which, dated June, 1918, has just arrived. It is about the form and size of the Journal of Industrial and Engineering Chemistry, is well printed on good paper, includes 156 pages and many illustrations. The original matter covers 84 pages, after which are about forty pages of abstracts of general chemical literature, and of patents. An interesting feature is the inclusion of a number of essays of a philosophic tone, relating to the economic issues at present and that may arise after the war. This section is termed "Organization economique." The number closes with two pages of book reviews.

The copy in hand contains no advertisements, a special notice being printed on the back of the title-page to the effect that an order of the French Government forbids advertisements in copies intended for transmission to other countries.

From the numerous chemical formulas we get the gratifying information that French chemists have at last adopted N instead of Az as a symbol, but unfortunately they still continue to write the exponents as superiors. Let us hope that in this particular also they will soon be able to say "Nous avons changé tout cela."

HENRY LEFFMANN.

EDIBLE OILS AND FATS. By C. Ainsworth Mitchell, B.A., F.I.C. London, Longmans, Green and Company, 1918. 123 pages, contents, bibliography, and index, illustrations. 8vo. Price, $2.00 net.

This is one of the series of monographs on industrial chemistry, to be written by specialists, under the editorial supervision of Sir Edward Thorpe, C.B., LL.D., F.R.S. Mr. Mitchell is so well known as an industrious and competent worker in the field to which the book is devoted that we are assured that it will be satisfactory. The field is, however, one that has been extensively studied and extensively discussed in the literature of chemistry of recent years, so that little new can be expected. The work includes concise statements of the composition and properties of the edible fats and oils, methods of extracting them from the raw materials and purifying and preparing them for the market. Many analytic data are also given.

Among the items of special interest is the description of some of the standard methods of manufacturing commercial butter-substitutes. An extensive bibliography is appended.

It is interesting to note that while France, Italy and the United States have adopted officially the glycerol-soda method for determining the volatile acids in butter-fat and its substitutes, English practice still adheres to the old alcohol-soda procedure. We cannot, of course, expect simplified spelling of chemical terms in an English book, but there seems to be no reason why the term "glycerol" should not be used, nor why the older term if used should be spelled "glycerin" on page 46 and "glycerine" on page 103. The difficulties that arise in consequence of differing terminology in the two English-speaking nations are often in evidence, for example, "peanut," "earth-nut" and "groundnut" are not found in the index; for information concerning them one must look for "arachis."

HENRY LEFFMANN.

NOTIONS FONDAMENTALES DE CHIMIE ORGANIQUE. Par Chas. Moureu. Paris, Gauthier-Villars, 1918. Fifth edition, 548 pages, 8vo.

The fourth edition of Prof. Moureu's book was reviewed in this journal three years ago. The text makes no pretensions to being a laboratory manual. The author confines himself entirely to his chosen task of presenting the theory of the subject, and omits all experimental directions. The logic of this position is evident. The student is sure to have a manual at hand. Even if he had not, the attempt to follow the brief recommendations in his text-book could result only in disaster.

Although the general plan of treatment remains unaltered, the fifth edition is somewhat larger than the fourth. The additional space has been devoted to a more extended treatment of stereochemistry, and of the relations between chemical constitution and physical properties. A brief but excellent chapter upon dye-stuffs has been added.

A careful reading of the fifth edition has confirmed the reviewer in his opinion that this is the best text-book of organic chemistry that has yet seen the light. It is almost the only one that can be read through as a whole with interest and pleasure. The fact that five editions have been called for in fifteen years is evidence of the wide recognition of its merits in France and the neighboring countries. It is unfortunate that no English translation exists for the use of students in Great Britain and the United States. Such a translation would facilitate to a marked degree the study of a subject of considerable difficulty, and of great and growing importance.

ROBERT H. BRADBURY.

VAN NOSTRAND'S CHEMICAL ANNUAL, Fourth Issue. Edited by John C. Olsen, A.M., Ph.D.; assistant editor, Maximilian P. Matthias, Ch.E. New York, D. Van Nostrand Company, 1918, XVIII + 778 pages. 12mo. Price, $3.00 net.

Four years have elapsed since the appearance of the third issue of this handbook. In the present edition, the molecular weights and factors have been recalculated to correspond to the international atomic weights for 1917.

New tables have been added concerning properties of the elements; calibration and true volume of glass vessels; use of indicators; properties of oils, alloys, glass, etc.; specific gravity; vapor pressure; units of weights and measures; capacity of tanks; conversion of units of heat, electricity, temperature, etc.; freezing point mixtures. Other tables have been revised in accordance with recently published data. The frontispiece is a portrait of Ira Remsen.

JOSEPH S. HEPBURN.

PUBLICATIONS RECEIVED.

Michigan State Board of Health: Forty-fourth and forty-fifth annual reports of the Secretary for the fiscal years ending June 30, 1916, and June 30, 1917. 243 pages, illustrations, 8vo. Lansing, State printers, 1917.

Canada Department of Mines: Mines Branch. Bulletin No. 22 to 26. Analyses of Canadian Fuels, in five parts, compiled by Edgar Stansfield, M.Sc., and J. H. H. Nicolls, M.Sc. 5 pamphlets, 8vo. Ottawa, King's printer, 1918.

U. S. Tariff Commission: Tariff Information Series—No. 4. The button industry. 125 pages, 8vo. Washington, Government Printing Office, 1918.

U. S. Bureau of Mines: Bulletin 123. Analyses of mine and car samples of coal collected in the fiscal years 1913 to 1916 by Arno C. Fieldner, Howard I. Smith, J. W. Paul and Samuel Sanford. 478 pages, 8vo. Monthly statement of coal mine fatalities in the United States, April, 1918. 23 pages, 8vo. Technical paper 189. Temperature-viscosity relations in the ternary system $CaO—Al_2O_3—SiO_2$ by Alexander L. Field and P. H. Royster, 36 pages, illustrations, plate, 8vo. Washington, Government Printing Office, 1918.

U. S. Coast and Geodetic Survey: Results of magnetic observations made by the U. S. Coast and Geodetic Survey in 1917 by Daniel L. Hazard, Chief, Division of Terrestrial Magnetism. 64 pages, 8vo. Price, 10 cents. Results of observations made at the U. S. Coast and Geodetic Survey Magnetic Observatory near Honolulu, Hawaii, 1915 and 1916 by Daniel L. Hazard, Chief, Division of Terrestrial Magnetism. 101 pages, plates, 4to. Price, 30 cents. Results of observations made at the U. S. Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1915 and 1916 by Daniel L. Hazard, Chief, Division of Terrestrial Magnetism. 96 pages, plates, 4to. Price 40 cents. Washington, Government Printing Office, 1918.

U. S. Department of Agriculture: Bulletin No. 607. Tests of the absorption and penetration of coal tar and creosote in longleaf pine by Clyde H. Teesdale and J. D. MacLean. 43 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1918.

Michigan College of Mines: Year book 1917–1918. Announcement of courses for 1918–1919. 115 pages, maps, 12mo. Houghton, Mich., College, 1918.

Western Australia: Interstate Forestry Conference, Perth, 1917. Report of University Timber Tests, 1917: Investigations Nos. 1 and 2 by Alfred Tomlinson, M. Sc. 7 pages, plates, folio. Perth, Government printer, 1918.

Athenæum Subject Index to Periodicals 1916: Issued at the request of

the Library Association of the United Kingdom. Education and Child Welfare. 20 pages, quarto. London, The Athenæum, 1918. Price, one shilling.

Colorado School of Mines: Circular of Information. Chromite by J. C. Williams, assistant director, Experimental Ore Dressing and Metallurgical Plant. 4 pages, quarto. Golden, Col., 1918.

U. S. Senate: Sixty-fifth Congress, second session. Construction of concrete ships. Letters and reports submitted on the cost, plans and advantages in the construction of concrete ships as submitted by constructing engineers to the chairman of Emergency Fleet Corporation and the Senate Commerce Committee. 58 pages, 8vo. Washington, Government Printing Office, 1918.

U. S. Reclamation Service: List of engineering articles No. 3. Reprinted from the fifteenth and sixteenth annual reports of the U. S. Reclamation Service. 31 pages, 8vo. Washington, Government Printing Office, 1918.

Your Business and War Business: A handbook on industrial adjustments by Harold G. Moulton. 23 pages, 8vo. Chicago, Union League Club, 1918.

The Peat Industry. C. C. OSBON. (*U. S. Geological Survey*). —The peat industry in the United States was prosperous in 1917, for the quantity of peat sold exceeded that in any preceding year. The peat sold in 1917 amounted to 97,363 short tons, a quantity greater by 44,857 tons, or about 85 per cent., than that sold in 1916, and by 42,220 tons, or nearly 77 per cent., than the record annual sales, 55,143 tons, established in 1911.

The average price received for peat in 1917 at the point of consumption was a little more than $7.29 a ton, and the gross market value of the output was $709,900, a gain over 1916 of 26 cents in average price per ton, and of $340,796, or about 92 per cent., in market value.

The total number of plants producing peat in the United States in 1917 was 18, an increase of 5 over 1916. All the producers operating in 1916 except two contributed to the output in 1917, and seven companies that were not represented in that year reported commercial production. Many new companies were organized in 1917 that did not complete their plants in time to contribute to the year's output. The plants known to be at work in 1917 were distributed as follows: California, 2; Florida, 2; Illinois, 2; Indiana, 1; Massachusetts, 1; New Jersey, 5; New York, 3; Pennsylvania, 1; and Virginia, 1.

All the producers reported that the demand for peat exceeded the supply, and some stated that, on account of railroad embargoes and the scarcity of labor, they were unable to meet the demands of their regular customers. Improvements designed to increase production in 1918 were made to substantially all the peat plants operated in 1917.

CURRENT TOPICS.

The Duty of the Employer in the Reconstruction of the Crippled Soldier. DOUGLAS C. MCMURTRIE, Director, Red Cross Institute for Crippled and Disabled Men, New York City.—Soon after the outbreak of present hostilities the European countries began the establishment of vocational training schools for the rehabilitation of disabled soldiers. They had both the humanitarian aim of restoring crippled men to the greatest possible degree and the economic aim of sparing the community the burden of unproductivity on the part of thousands of its best citizens. The movement had its inception with Mayor Édouard Herriot of the city of Lyons, France, who found it difficult to reconcile the desperate need for labor in the factories and munition works while men who had lost an arm or a leg but were otherwise strong and well were idling their time in the public squares. He therefore induced the municipal council to open an industrial school for war cripples which has proved the example and inspiration for hundreds of similar schools since founded throughout France, Italy, Germany, Great Britain, and Canada.

The disability of some crippled soldiers is no bar to returning to their former trade, but the injuries of many disqualify them from pursuing again their past occupation. The schools of training prepare these men for some work in which their physical handicap will not materially interfere with their production.

The education of the adult is made up largely of his working experience. The groundwork of training in his past occupation must under no circumstances be abandoned. The new trade must be related to the former one or be, perhaps, an extension or specialization of it. For example, a man who had done manual work in the building trades may by instruction in architectural drafting and the interpretation of plans be fitted for a foreman's job, in which the lack of an arm would not prove of serious handicap. A trainman who had lost a leg might wisely be prepared as a telegrapher, so that he could go back to railroad work, with the practice of which he is already familiar. Whatever training is given must be thorough, for an adult cannot be sent out to employment on the same basis as a boy apprentice. He must be adequately prepared for the work he is to undertake.

The one-armed soldier is equipped with working appliances which have supplanted the old familiar artificial limb. The new appliances are designed with a practical aim only in view; they vary according to the trade in which the individual is to engage. For example, the appliance for a machinist would be quite different from that with which a wood turner would be provided. Some appliances have at-

tached to the stump a chuck in which various tools or hooks can interchangeably be held. The wearer uses these devices only while at work; for evenings and holidays he is provided with a "dress arm" which is made in imitation of the lost natural member.

An important factor in the success of re-educational work is an early start, so that the disabled man shall have no chance to go out unemployed into the community. In even a short period of exposure to the sentimental sympathy of family and friends, his "will to work" is so broken down that it becomes difficult again to restore him to a stand of independence and ambition. For this reason, therefore, the plan for his future is made at as early a date as his physical condition admits, and training is actually under way before the patient is out of the hospital.

In the readjustment of the crippled soldier to civilian life, his placement in employment is a matter of the greatest moment. In this field the employer has a very definite responsibility. But the employer's duty is not entirely obvious. It is, on the contrary, almost diametrically opposite to what one might superficially infer it to be. The duty is not to "take care of," from patriotic motives, a given number of disabled men, finding for them any odd jobs which are available, and putting the ex-soldiers in them without much regard to whether they can earn the wages paid or not.

Twelve men sent to twelve jobs may all be seriously misplaced, while the same twelve placed with thought and wisdom and differently assigned to the same twelve jobs may be ideally located. If normal workers require expert and careful placement, crippled candidates for employment require it even more.

The positive aspect of the employer's duty is to find for the disabled man a constructive job which he can hold on the basis of competency alone. In such a job he can be self-respecting, be happy, and look forward to a future. This is the definite patriotic duty. It is not so easy of execution as telling a superintendent to take care of four men, but there is infinitely more satisfaction to the employer in the results, and infinitely greater advantage to the employee; and it is entirely practical, even in dealing with seriously disabled men. With thoughtful placement effort, many men can be employed directly on the basis of their past experience. With the disabled soldiers who profit by the training facilities the government will provide, the task should be even easier. This, then, constitutes the charge of patriotic duty upon the employer: To study the jobs under his jurisdiction to determine what ones might be satisfactorily held by cripples; to give the cripples preference for these jobs; to consider thoughtfully the applications of disabled men for employment, bearing in mind the importance of utilizing to as great an extent as possible labor which would otherwise be unproductive; to do the returned soldier the honor of offering him real employment, rather than proffering him the ignominy of a charity job.

Increasing the Yield of Sugar Cane. ANON. (*The Journal of Industrial and Engineering Chemistry*, vol. 10, No. 5, p. 407, May, 1918.)—According to the *Little Journal* for April, Mr. C. F. Eckart, a leading authority on sugar planting in Hawaii, has developed a process in the raising of sugar cane in Hawaii which reduces the cost of labor 50 to 70 per cent. and increases the yield 28 per cent. His process consists in laying yard-wide strips of paper longitudinally over the rows, holding them in place by covering the edges with cane-field trash. The paper must be strong enough to keep down the weeds, but not strong enough to kill the young cane. Five or six weeks after applying the paper the weed seeds that can germinate have done so and their sprouts are smothered, while the shoots of the sugar cane, being stiff and sharp, have either come through the paper or show their presence by little tent-like elevations in the paper, which can be split with long knives by laborers passing between the rows.

An attractive problem in industrial research was presented to the Arthur D. Little, Inc., laboratories when the question of making paper from bagasse suitable for this purpose was put to them. Many sorts of paper have been made from bagasse, but they have tended to be hard and tinny, whereas there was required here a paper which would be strong enough to withstand the Hawaiian rainfall and yet give way under constant gentle pressure. Also, it had to be dark in color and unusually cheap. This problem has been solved and plans are being made for a paper mill to take care of Mr. Eckart's plantation. Some interesting pictures appear in the *Little Journal*, comparing cane four and one-half months after planting, one showing cane which has received the Eckhart treatment, another which was cultivated and hoed in the usual manner.

Making Foundations with a Pile Driver. ANON. (*Scientific American*, vol. 118, No. 16, p. 357, April 20, 1918.)—A unique method of building foundations which has found extended use in France and Belgium has been developed by the engineer Louis Dulac. This method consists, in its most general terms, in consolidating the ground by blows from a weight without removing any material whatever. The resulting holes are then filled with stones or some aggregated material, likewise under pressure; and by making borings sufficiently close there are thus obtained a series of subterranean columns well fixed in the earth.

To bore the holes and pack them mechanically a modified pile driver is used. Three hammer heads are provided. The perforating hammer is conical, weighs approximately two and a half tons, and is about 33 inches in diameter. This has a point of high-grade steel. A packing hammer of cast iron, ogival in shape, is three or four inches smaller than the borer. The finishing hammer is in the form of a truncated cone. Unlike the two others which work with the point down, this is used with its smaller base upward. When the

hole made by the first head is sufficiently deep, judged by the gradual diminution of the distance which the head penerates with each blow, tamping is proceeded with, giving the desired vertical and lateral compression of the earth and providing a base for the column. For this there is thrown into the hole a concrete mixture. Under the blows of the tamping hammer the mass gradually forces the bottom of the hole out flatter; but the resistance offered by the already partly compacted earth is sufficient to spread the cement plug out sideways. The result is a solid block in the bottom of the hole. This is filled with any appropriate concrete mixture.

The Present Economic and Social Conditions as Results of Applied Science and Invention. G. W. PERKINS. (*The Scientific Monthly*, vol. 6, No. 3, p. 223, March, 1918).—During the last quarter of a century men of science have been so engrossed in the fascinating problems on which they have been working that they have taken little or no time to inform the public as to the practical effect that modern scientific inventions were bound to have on every-day life. These inventions have been placed in the hands of the people of the world within the last third of a century, and their application to business and social affairs has overthrown and carried away a countless number of old practices and precedents.

As man-made laws are the outgrowth of centuries of effort, it did not seem possible that anything would come into the world that would set all this cumulative knowledge and experience to naught almost overnight. Such, however, is the actual situation; but a vast majority do not realize this—do not at all understand it. It is also true that a large number of the more intelligent class have refused to accept the new conditions in which we live and have insisted on continuing under the old system, following old precedents and practices. As a result, a mighty conflict has engaged us and will continue to engage us until people realize that a mighty upheaval has taken place; that we have entered a new world of thought and action, dominated almost wholly by the discoveries of science within the last half century; that new codes of business morals, of finance, of industry are being set up; and that it behooves us all to give the best thought, the broadest vision, the most unselfish devotion to the erection of a new structure that will be in harmony with modern economic needs.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA